AN ANALYSIS OF ALTERNATIVE METHODS FOR LOADING PROVISIONS ABOARD AOEs 1 AND 2

David Karl Anderson

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN ANALYSIS OF ALTERNATIVE METHODS FOR LOADING PROVISIONS ABOARD AOEs 1 AND 2

by

David Karl Anderson

June 1974

Thesis Advisor: J. P. Hynes

Approved for public release; distribution unlimited.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN ANALYSIS OF ALTERNATIVE METHODS FOR LOADING PROVISIONS ABOARD AOEs 1 AND 2		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; (June 1974)
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) David Karl Anderson		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE June 1974
		13. NUMBER OF PAGES 169
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Approved for public release; distribution unlimited.

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fast Combat Support Ship
AOE
Palletized Provision Cargo

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

One of the Fast Combat Support Ship's (AOE) functions is the delivery of dry, freeze, and chill provisions to afloat combat units. The present ship characteristics do not provide for handling and stowage of palletized provision cargo.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
(Page 1) S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Significant savings in material handling time and cost can be realized from handling cargo in palletized units. A comparison is made between the present handling procedure on AOEs 1 and 2 and five alternative systems. Three of the alternatives will be shown to be infeasible because of the dimensions and physical constraints of the AOE hull. Comparison measures of effectiveness include total elapsed loading time, loading cost per measurement ton of cargo and qualitative considerations.

In conclusion, recommendations for modification of the AOEs 1 and 2 to permit palletized handling of provisions cargo are prioritized.

An Analysis of Alternative Methods for Loading Provisions Aboard AOEs 1 and 2

by

David Karl Anderson
Lieutenant Commander, United States Navy
B.A., University of Washington, 1960

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
June 1974

ABSTRACT

One of the Fast Combat Support Ship's (AOE) functions is the delivery of dry, freeze, and chill provisions to afloat combat units. The present ship characteristics do not provide for handling and stowage of palletized provision cargo.

Significant savings in material handling time and cost can be realized from handling cargo in palletized units. A comparison is made between the present handling procedure on AOEs 1 and 2 and five alternative systems. Three of the alternatives will be shown to be infeasible because of the dimensions and physical constraints of the AOE hull. Comparison measures of effectiveness include total elapsed loading time, loading cost per measurement ton of cargo and qualitative considerations.

In conclusion, recommendations for modification of the AOEs 1 and 2 to permit palletized handling of provisions cargo are prioritized.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF DRAWINGS AND ILLUSTRATIONS

I. BACKGROUND

A. THE AOE FUNCTION

The Fast Combat Support Ship (AOE) is designed to provide afloat operational combat units such as a CVA (Aircraft Carrier) task force with ammunition, fuel and provisions. A typical CVA task force consists of an aircraft carrier and destroyers, auxiliary and other combatant ships supporting the CVA task force mission. The AOE accomplishes this function via underway-replenishment methods including connected along-side highline transfer and vertical replenishment.

The AOE supports this variety of ships on an individual customer basis. Because of the wide range of individual ship's requirements and the numerous line items of provisions carried by the AOE, this ship must be capable of issuing customer ship requirements at random within short time frames to meet the individual ship's needs. However, the bulk of the AOE capacity is dedicated to the stowage and handling of fuel and ammunition. These stowage capabilities are complemented by 14 fuel-pumping stations and six ammunition elevators capable of lifting palletized loads.

The dry, freeze, and chill provisions stowage is not similarly equipped to handle palletized cargo and constitutes the area of emphasis for this study. Hold No. 5 is the designated provisions cargo stowage area on all AOEs.

This hold consists of three upper levels of split-refrigerated and dry-provisions cargo. The refrigerated spaces are served by one 85-pound capacity vertical package conveyor. The dry-cargo spaces are served by a second 85-pound vertical package conveyor. The USS Seattle (AOE 3) and USS Detroit (AOE 4) have a 9000-pound capacity pallet elevator serving the dry-provisions spaces vice the 85-pound package conveyor. See Fig. 1 for the details of the Hold No. 5 layout aboard AOEs 1 and 2.

B. PROVISIONS LOADING

The method for loading provisions is very similar aboard all four AOEs even though AOEs 3 and 4 have an elevator capable of lifting and lowering palletized provisions. The reason for this similarity is that the provisions storeroom spaces on AOEs 3 and 4 are not designed for fork lift operation although palletized units can be delivered to the storeroom. Only during the last 12 months have minor modifications been made to AOE 4 so that minimal fork lift operations can be achieved in these spaces.[1]

Chapter III describes the loading and issue procedures from the Hold No. 5 spaces aboard AOEs 1 and 2. These evolutions are labor intensive requiring significant time, manpower resources and expense. The typical provisions loadout is accomplished by contract or civil service stevedores and is subject to the rates and rules negotiated in

---

[1] USS Detroit message 101125Z May 1973.

applicable union contracts. Appendix H illustrates the historical escalation of stevedore rates for the port of Seattle, Washington, where AOEs 1 and 2 have been loaded out with initial deployment provision loads during the past six years. Tied to the escalating labor rates are numerous work rules requiring such additional charges as automatic overtime for certain skills, fixed skill requirements for certain positions, etc. For recent loadings, the stevedore cost has run $35.00 to $50.00 per measurement ton. This costs the Navy from $20,000.00 to $50,000.00 just to move 500 to 1000 measurement ton of provisions from the pier to the AOE storeroom, a total distance of less than 300 feet. This represents 8% to 10% of the value of the cargo.

The $35.00 to $50.00 per ton for loading provisions aboard the AOE compares unfavorably to the $8.00 to $18.00 per ton required to load palletized and hand-stow cargo respectively aboard conventional cargo and refrigerated stores ships. Additionally, the loading rate for provisions aboard AOEs 1 and 2 runs five to ten measurement ton per stevedore gang hour (all hand stowage) as compared to 12 to 15 measurement ton per hour aboard the conventional ship for similar cargo.

The total time for loading out provisions on the AOE depends on the total quantity to be loaded and the number of stevedore gangs available. The total time to load out an AOE in fuel, ammunition and provisions runs as high as 15 days with five to six days required for loading only the

provisions in Hold No. 5. This time has been reduced to three to four days by hiring stevedores on overtime but this is extremely expensive because of the ship's design and limited conveyor capacity. However, pending operations schedule for the AOE has on several occasions required rapid loading thus necessitating the use of premium labor.

If the AOE could achieve provision-loading rates of 20 to 25 ton per gang hour, which is achieved on many conventional cargo ships, the total time for the AOE provision loadout could be significantly reduced. These higher loading rates achieved on conventional cargo ships are achieved through the use of palletized stowage and handling of cargo which also involves fewer stevedores at less cost per ton. The approach of this study is to attempt to adopt a palletized cargo handling capability for provisions aboard the AOEs 1 and 2 to reduce time and costs.

C. PALLETIZATION OF CARGO

1. Advantages of Palletization

The major advantage of handling provisions in palletized loads is the reduction of handling costs per unit realized by the movement of material in larger loads with materials-handling equipment. Further cost savings are accrued because palletization and mechanized handling provide faster movement of provisions, reduces the time for loading and handling, and reduces produce damage as well as pilferage in transit and storage.

Stowage of provisions aboard ship in palletized loads has several additional advantages. Irregular shaped items can be palletized into stable loads which in turn stabilize stacks of material. Handling of unitized provisions is acknowledged to be safer and the unitization of chill and freeze provisions provides more uniform temperature and moisture control.

Significant reductions can also be achieved in the time and cost of physical inventories if provisions are stored on pallets in known quantities. More accurate inventories and faster handling of palletized loads contribute to better customer service.[2]

2. Disadvantages of Palletization

First of all, the activity or ship must have the capability to handle palletized loads. This means that adequate space must be available to store palletized loads, the supporting deck or floor must be of sufficient strength to bear the weight of unitized loads and the required mechanized handling equipment must be available for use as required. Fork lifts, cranes, pallet jacks or other equipment must be available in sufficient quantity and capacity to move the palletized material over distances and obstacles peculiar to the particular installation.

Although the overall damage to cargo is minimized when material is palletized, that damage that does occur

---

[2] Apple, James M., Material Handling Systems Design, p. 72, Ronald Press Co., New York, 1972.

due to mishandling affects much more than a single package or box. The whole pallet may be involved.

The cost and effort of unitizing and de-unitizing cargo must be considered. This effort on the AOEs 1 and 2 is presently significant, but, even if all of the provisions could be stowed on pallets, this effort would not be eliminated because issue procedures require the AOE to tailor issue quantities to the customer ship's individual requirements. Most provisions are delivered to the AOE for loadout in palletized loads. The unitizing and de-unitizing effort can be minimized and other advantages of palletized loading realized by leaving the cargo in its original palletized configuration until the latest possible time, which would be the cargo's ultimate issue or transfer in less than palletized quantity.

Unfortunately, the available provisions spaces in Hold No. 5 on the AOEs 1 and 2 are not large enough to accommodate a fully palletized 1000-measurement ton load. All provisions are not marketed in uniform boxes and packages and the placing of the various boxes on a standard-size pallet for ease in handling invariably wastes some space within the pallet load. Overhead height restrictions also dictate optimal pallet load heights for stacking or additional space will be lost. The pallets themselves occupy valuable cubic space in the storeroom thus reducing the storage capacity achieved in tightly stowed loose cargo.[3]

---

[3] Apple, James M., p. 73

D. SCOPE OF THE PROBLEM

The elapsed time and high cost to load dry, freeze, and chill provisions aboard AOEs 1 and 2 are the basic factors under attack in this study. In addition to the present system, five alternative methods, all considered to be practical approaches to reducing loading time and cost, will be considered. However, an important point in considering alternatives is the impact each will have on issue operations. Any alternative which improves loadout cost or time at the expense of interfering with the operational mission is unacceptable.

E. OBJECTIVES

The objective of this study is to identify an alternative system which accomplishes the following for AOEs 1 and 2: (1) reduces the average cost per measurement ton to lift aboard and stow provisions; (2) reduces the total time of provisions loading in terms of loading shifts;[4] (3) reduces the number of men assigned to present loading operations; (4) minimizes the number of sailors required for issue operations; (5) minimizes the present issue times; and (6) achieves some qualitative advantages over present operations.

The basic approach to achieving these objectives is to provide the capability of handling provisions cargo in

---

[4] One loading shift is equal to one eight-hour working period regardless of the number of stevedore gangs assigned.

palletized quantities wherever possible to reduce costs and manpower requirements in materials handling.

F. METHOD OF INVESTIGATION

The author initially became familiar with the provision loading problems of the AOE while assigned to the Water Freight Department of the Naval Supply Depot Seattle (July 1966 - March 1968). During this period NSD Seattle loaded the USS Sacramento (AOE 1) and the USS Camden (AOE 2) a total of three times. The author was directly involved with the cargo staging and coordination of stevedore operations and thus possesses personal experience in the area. The alternatives discussed in this study were developed by the author as a product of studying numerous cargo ship loading systems while at NSD Seattle and from discussions with design engineers at Naval Shipyard Puget Sound and the Naval Ship Engineering Center, Hyattsville, Maryland. In addition, data on policies, requirements, costs, operating statistics and professional opinions and advice were obtained from the following sources: (1) the Naval Ship Engineering Center provided study data on AOEs 3 and 4 operations, proposed ship alterations and study data on proposed modifications to AOE provision storerooms in Hold No. 5 to permit handling of palletized cargo with fork lifts; (2) Commanders Service Force Atlantic and Pacific staff personnel provided confirmation of basic assumptions concerning operating mode, tonnage requirements, expected ship life and scenario; (3) Naval Supply Center Puget Sound and Naval Supply Center

Norfolk provided historical AOE provision-load tonnage and cost data. NSC Norfolk also provided data concerning use of a pallet elevator on AOE 3; and (4) MTMTS (Military Traffic Management and Terminal Service) Western Area and the Pacific Northwest Outport provided data on stevedore assignments, union rules and pay scales under contracts negotiated with the International Longshoremen's and Warehousemen's Union by the Pacific Maritime Association on behalf of its member-employer organizations.

The basic alternatives were discussed in detail with design personnel at Naval Shipyard Puget Sound, which was the design activity for USS Sacramento and the follow-on AOE ships, to determine rough cost estimates, structural feasibility and ship design constraints.

During the period 31 January to 2 February 1974, the author observed the loading of the USS Sacramento at Pier 91 in Seattle, Washington. During this period loading times, personnel requirements, costs and other data were obtained including physical locations and dimensions of installed equipment and other ship structures. Loading and issue procedures, equipment and personnel requirements and alternative methods of handling provisions aboard the ship were discussed with USS Sacramento personnel during this visit.

Additional operating and issue data was acquired from the USS Camden for the deployment period 20 February 1973 through 12 December 1973.

Following the observation of the loading of the USS Sacramento, the author visited the Naval School of Transportation Management at Oakland, California, to test those alternatives involving the use of booms, cranes, winches and other conventional cargo-handling equipment on the school's scale model Cargo Rigging Strain Demonstrator. During this same visit to Oakland, California, the author also observed the pallet conveyors and elevators aboard the USS San Jose (AFS 7) used in loading provisions.

Data was also acquired from commercial sources on telescoping hydraulic booms, cranes and other equipment discussed in this study. A great number of ideas, suggestions and subsequent combinations resulted from the above investigation and are incorporated in this report.

G. SCENARIO

The basic scenario applied to this study for purposes of modeling and consistency is the mission of the AOE to support a CVA task group. This function in terms of provisions requires 1000-measurement ton every 30 days on line. An annual six-month deployment by the AOE would involve an initial loading in CONUS plus an equivalent of two additional replenishments of the AOE provisions stocks during the deployment. In the Pacific Fleet these replenishments are normally accomplished in port and result in a total of 3000 measurement ton of provisions loaded aboard the AOE annually. For purposes of illustration, all loading costs will be

based on stevedore rates effective in the port of Seattle, Washington, for 1973.

H. ASSUMPTIONS

The following assumptions are identified as basic parameters used in discussing the AOE provisions-loading problem and analysis of the several alternatives:

1. Ship's Life

It will be assumed that the AOE has a remaining useful life of at least 15 years and that the scenario provided above will remain basically the same over the AOE life span. Each ship will average one deployment of six months annually.

2. Load Requirement

The standard load of provisions for the AOE will be 1000-measurement ton of freeze, chill, and dry (600 short ton) which is required for 30 days support of a CVA task force. Seventy per cent of this load can be stowed on pallets.[5]

---

[5] Naval Ship Engineering Center, Addendum to Cost and Feasibility Study of Recommended Improvements to AOE Class Provisions Handling and Stowage System, 7 March 1972. This study investigates the feasibility of placing a 750 short ton load aboard the AOE. On page 1-1, a summary of requirements calls for 77% of the total 85,396 cubic feet of required storage to be used for palletized cargo. However, this entire load cannot fit into Hold No. 5. Page 3-2 calls for 69.4% of the stowage space in Hold No. 5 to be used for palletized stowage. For ease of computation, the author has chosen 70%. The sensitivity of this assumption is examined in Section V.C.

3. Cost Factors

The stevedore rates and equipment costs as documented in Appendix H are representative of current costs and these costs will escalate in the future at a 6% per annum rate as illustrated in Appendix G.

4. Ship Alterations

It will also be assumed that basic ship alterations required for fork lift operations within the AOE provisions spaces will have been accomplished for alternatives B through F. These alterations include pending alterations AOE 83, 95 and 96 to accomplish the following: (a) removal of the existing deck insulation, grating and shoring system; (b) installation of new insulation (designed to support fork lift operations on the deck) in refrigerated spaces; (c) installation of heavy duty deck grating over the entire deck areas of each compartment; (d) installation of expanded metal overhead panels in each level for use of shoring battens with new deck grating; (e) recess lights into spaces between overhead stringers, and re-route refrigeration ducts and other overhead obstructions to provide clear eight-foot grating-to-grating clearance for fork lift truck operation and double tier pallet stowage; (f) install telescopic battens in each hold level; (g) setting elevator and conveyor stops to align platform with new deck grating in each compartment; (h) modification of elevator and conveyor doors at all levels to provide a seven foot six inch clearance for fork lift operations; (i) installation of protective devices

around miscellaneous piping, stantions, etc., for fork lift truck operations at all levels; (j) modification of trunk area to provide stowage and tie downs for fork lift stowage; (k) installation of fork lift battery chargers on the main deck and a battery-charger outlet in each storeroom level; and (l) providing fork lift access between spaces 2-174-0-AA and 2-186-0-AA, 3-174-0-AA and 3-186-0-AA, and 4-174-0-AA and 4-186-0-AA, by either removing the bulkhead (necessitating insulating and refrigerating the entire level) or installing doors and ramps of sufficient size to accommodate a loaded fork lift.

Ship alterations AOE 83, 95 and 96 provide for changes in the refrigeration capacity of the AOE ships by changing some dry-provisions spaces to refrigerated spaces in addition to providing fork lift operating capability within those spaces. Summarized above are only those actions required to provide fork lift capability to accommodate palletized loading, storage and issue activities. The subject of refrigerated-space adequacy and the optimal mix of refrigerated and dry-provisions spaces on the AOE is beyond the scope of this study.

5. Robot Gear

It will be assumed that a "robot" will be used with all crane or yard and stay-lift operations to minimize stevedore labor costs. A robot is shown in operation in Fig. 2.

6. Deployment

The normal deployment is assumed to be six months in length involving one CONUS loading of provisions and the equivalent of two additional inport loadings during deployment.

7. Issue Policies

It will be assumed that there will be no changes in current issue policies. The AOE will continue to respond to customer ship requirements on an individual basis requiring random access to line items of provisions carried in stock.

8. Loading Shifts

For consistency in computation and ease of comparison, it will be assumed that all loading evolutions will be accomplished during regular day shifts of eight working hours to minimize total cost.

II. CRITERIA FOR SELECTING THE BEST ALTERNATIVE

The following criteria will be applied to each of the alternatives discussed in this study as attributes for measuring benefits and comparing the alternatives. To justify recommendations and conclusions these criteria were selected as the result of research of methods of cost-benefit analysis and inputs from organizations identified in Paragraph F of Chapter I.

A. PRESENT VALUE OF SAVINGS

A comparison of the present value of cost savings, discounted at the Department of Defense (D.O.D.) discount rate of ten per cent as prescribed in D.O.D. Instruction 7041.3, will be made between present operational loading methods and each of the alternatives over a 15-year remaining life cycle assumed for the AOE. Costs will be based on 1973 ILWU wage scales applicable to Seattle, Washington. Savings resulting from changes in shipboard personnel assignments required for issue operations will not be costed out. Costs will be developed only for stevedores and equipment required in the loading evolution. The basic unit of measure for developing cost savings under each alternative will be a hypothetical dollar cost of loading one measurement ton of cargo (40 cubic feet equals one measurement ton) based on constructed loading times from a simplistic model priced at imperical ILWU extra labor rates.

B. MANPOWER ANALYSIS

The numbers of personnel required in each alternative will be identified for loading provisions aboard the AOE and for underway issue operations. It must be pointed out that stevedore manpower reductions are direct savings to the Navy, whereas reductions in shipboard-personnel assignments for alternative issue systems reflect only a relative reduction in issue costs and cannot be construed to represent a real reduction in manpower requirement for the ship. The reason for this difference is that stevedores are required only for the singular function of loading the ship, while shipboard personnel are required to man battle stations, maintain assigned spaces within the ship and provide internal operational services to the ship besides any individual assignments to the issue function. Their individual release from the issue function only provides additional time for the sailor to devote to his other duties.

The number of personnel assigned under each alternative is a relative measure of effectiveness. Although this number typically varies during underway replenishments depending on the volume of issues, shipboard personnel will be identified for the purposes of: (1) selecting material at random from within a storeroom to fill a specific customer ship's requirement; (2) assembling the order in a unitized load for lift to the customer ship; and (3) control of the provisions cargo and staging for lift to the customer ship.

C. EQUIPMENT REQUIREMENTS

The additional equipment requirements for each alternative will be identified to quantify the relative investment. In each case, the changes in the following equipments will be identified by size and type: (1) fork lifts; (2) cranes; (3) elevators; (4) conveyors; and (5) robots. The quantity of equipment in each category above will be compared between the alternatives.

D. ELAPSED LOADING TIME

A significant factor in managing commercial cargo ships is the nonproductive time spent loading and unloading cargo in port. This principle is applied with the alternatives identified herein in terms of the number of eight-hour shifts required to load the assumed standard 1000 measurement-ton provisions load aboard the AOE. Because of the wide variability in issue volume and times, the issue times for underway operations will not be quantified.

E. INTEGRATION OF ACTIVITIES

The integration of activities aboard the AOE during the issue process is subjective in nature but is an extremely important consideration. The ship's multimission for distributing material to afloat units in widely varying quantities and mixes between ammunition, fuel, provisions and other materials creates a complex mix of demands for shipboard resources. Alternatives must be evaluated in terms of their: (1) flexibility and compatibility with issue

operations conducted simultaneously with products other than provisions; (2) utilization of materials-handling equipment, particularly fork lifts, which are heavily used for ammunition issues; and (4) traffic flow including cross-product interference.

F. PRODUCT QUALITY

Product quality is an important consideration for customer ships, particularly for freeze and chill provisions. Exposure for any length of time to other than a proper refrigerated environment, whether it be warm or too cold in the case of many fresh chill provisions, will rapidly diminish the product's normal condition, keeping ability and desirability. Exposure of these items to ambient temperatures during cargo issue must be kept to the absolute minimum. Product quality of dry provisions as well as freeze and chill will also include susceptibility to damage. A third category included under product quality is pilferage and control. Each of these attributes will be subjectively addressed for each alternative.

G. STRUCTURAL CHANGES

Structural changes required for installation of any proposed alternative system or supporting equipment will rapidly increase initial investment. For each of the alternatives the following structural changes will be identified: (1) new equipment and fixture locations and installation; (2) relocation of existing equipment and fixtures; and (3) changes required in structural configuration of the ship.

H. SAFETY CONSIDERATIONS

Major potential safety hazards during loading and issue operations will be identified and oriented to each alternative on the basis of the operator's ability to: (1) limit the number of times that material must be lifted or moved by hand and equipment; (2) communicate safety conditions from one cargo handling position to another; (3) observe cargo movement throughout each continuous lift movement; and (4) minimize cross traffic interference, particularly with fork lifts.

I. OPERATIONAL RELIABILITY AND CAPABILITY

All of the alternatives provide viable methods of handling cargo under ideal conditions. However, the physical dimensions and existing design of the AOE presents varying degrees of limitation for each alternative system. The operating limitations of each system will be identified based on the opinion of experienced ship-loading personnel, equipment manufacturers, or cargo rigging research and experimentation by the author. Additionally, the opinions of shipboard personnel, stevedores and shipyard design personnel will be documented where available concerning the reliability and maintainability of candidate equipments.

It will be noted that a combination of design and operational limitations within the AOE dictate that several of the alternatives are infeasible. However, the author considers it worth-while to document these alternatives, their inherent potential, and AOE incompatabilities so that future

Mobile Logistic Support Ship specifications can take advantage of this study and eliminate cargo-loading problems similar to that presently existing in the provisions area aboard the AOEs.

III. ALTERNATIVES

The basic criteria for selecting the following alternatives was to identify systems and equipment that: (1) have demonstrated to be operationally effective in handling large quantities of cargo over a prolonged period of time; (2) are relatively readily available on the commercial market; and (3) are readily adaptable to most cargo ships with minimal structural alteration. Therefore, some of the current high volume cargo loading techniques such as large containerization and roll-on, roll-off, which require significant design inputs prior to the ship's construction, have not been considered. The alternatives under consideration will be referred to throughout the remainder of this report as A through F, respectively, for ease in reference.

A. EXISTING METHOD

Figures 3 and 4 diagramatically illustrate the flow of cargo through the present method of loading provisions aboard the AOEs 1 and 2. This is very similar to the method used on AOEs 3 and 4 with the exception that the AOEs 3 and 4 have a pallet elevator located amidship at frame 175 vice the package conveyor number 2 installed on AOEs 1 and 2.

1. Loading Procedure

The routine established in Seattle, Washington, for loading provisions on AOEs 1 and 2 is made up of three teams of stevedores which will be referred to as "gangs." However,

these "gangs" should not be confused with standard stevedore gangs identified in local ILWU labor contracts for hiring-hall purposes. The "gangs" used in this study are quantities of men selected for the loading of spaces aboard the AOE and are tailored to the specific physical requirements for materials handling found only on this type of ship.

The loading starts with an eight-man gang assigned to the dry-provisions spaces at frame 174 starting on the sixth deck (lowest level) and working up. The package conveyor number two at frame 175 is used to feed cargo to this gang in the storeroom for hand stowing.

A second eight-man gang simultaneously starts loading the refrigerated spaces at frame 186 starting on the fourth deck and working up to the second deck. The number three package conveyor at frame 196 is used to feed cargo to this gang which then hand stows the cargo in the storeroom.

A third gang of eight men is used alternately to stow refrigerated and dry cargo and provide backup capability for the other two gangs in case one of the package conveyors goes out of commission. Temporary failure of one of these conveyors during loading is a common occurrence. This third gang stows cargo which has been lowered by the five ton ship's crane located on the port side of the 01 deck at frame 183. The cargo is lowered by this crane through a series of small (7ft. X 9ft.) hatches located on the port side of the storerooms at frame 180. Because of the small size of this system of hatches great care must be taken in

lowering pallet loads of cargo to the stevedore gang in the storeroom. Hence, this is a very slow process and the loading rate for this gang is very low (five ton per hour). A small degree of list by the ship or any pendulous movement of the cargo while being lowered through this hatch system makes it very difficult to use this system.

The three gangs complement each other in loading the ship from the lower levels up. Two of the gangs may work on the same level from the fourth deck up. The gang working cargo via the crane and hatch system does not move up to a higher deck until the space is almost completely loaded, with the exception of the space under the square of the hatch. This space is usually occupied with cargo when the space is completely loaded and negates any future access to that space by the ship's crane until the cargo under the hatch is moved or issued. The square of the hatch is used for stowage of cargo on all of the levels when the ship is fully loaded. Once the gang working the crane and hatch system moves to an upper level, the storeroom can be completed only by the gang working from package conveyors No. 2 or No. 3. Premature stowage of upper levels, including the square of the hatch, would eliminate the flexibility of using the third gang in a lower level in case of a package conveyor malfunction.

The above sequence tracks the movement of provision cargo from the 01 deck on the AOEs 1 and 2 to the storeroom. The cargo is lifted in palletized loads from the pier to

the 01 deck by a mobile crane on the pier. Because the central part of the 01 deck is completely covered, the mobile crane must place the palletized cargo on the open wings of the 01 deck. From here the pallets of cargo are moved by fork lift to one of the two package conveyors, depending on whether the cargo is dry or refrigerated, or to the small ship's crane on the port side of the 01 deck for lowering to the third stevedore gang working the crane and hatch system.

The AOEs are normally moored starboard side to the pier in Seattle so that the ship's crane can be used as described above. If the ship was moored portside to the pier, the mobile crane on the pier would place cargo on the deck in a location which would either interfere with the ship's crane operations or increase the fork lift travel distance for feeding the package conveyors.

The ship's crane at frame 183 has been found to be very slow for lifting cargo from the pier up to the 01 deck and, if the ship is breasted from the pier 15 feet or more, the operational-lift radius limits the crane's capabilities to the point as to be impractical for use as a replacement for the mobile cranes presently used on the pier. Therefore, for loading of large quantities of provisions, the AOE is not considered self-sufficient. That is, the AOE is not adequately equipped to lift the cargo from the pier to the 01 deck, and must depend on pier-side crane support for this function. During a 1966 loading in Seattle, USS Sacramento (AOE 1) lay at anchor off the Naval Supply Depot Seattle

while being loaded with provisions from barges alongside. The inadequacy of the AOE ship's cranes required that a mobile crane be loaded on a separate barge and towed into position alongside the Sacramento to provide adequate lift capability.

In summary, the present loading procedure is to lift palletized units of cargo from the pier to the 01 deck with a mobile crane. The pallets are then moved by fork lift to the package conveyors where the pallets are broken down and fed, one box at a time, into the package conveyor. The stevedore gang in the storeroom pulls the boxes from the package conveyor and stows them, one at a time.

An alternate method of loading the ship is accomplished by transferring provisions from other Mobile Logistics Support Force ships to the AOE while both ships are underway. This operation is called a consolidation and may occur several times during an AOE deployment thus offsetting some of the inport loading requirement. During this operation palletized provisions are highlined or lifted by helicopter to the AOE and then moved by forklift to the package conveyors and broken down box by box and hand stowed as described above.

2. Issue Operations

Standard operating procedures and policies call for the AOE to issue provisions on a line-item basis and in the quantities specified by the customer ship. Orders are placed by the customer ship a few days in advance to allow

the AOE personnel to plan and organize the required issues to satisfy a sequential visit of customer ships during a given rendezvous. Customer demands are normally unrestricted except that units of issue for provisions are normally by the case or box vice individual can or package. For an individual customer the number of line items requisitioned, the quantity of each line item desired, and the frequency with which the ship orders are all independent variables. Therefore, the AOE must be able to issue various line items at random, in widely varying quantities, for any given issue period. Most orders are for small individual quantities of numerous line items. Operating personnel estimate that the AOE carries only six line items of provisions that are consistantly requisitioned in quantities equivalent to one pallet load or more by most customers ships.

To accomplish the issue, shipboard personnel select the line items and quantities required within the AOE storeroom. The individual cases and boxes of provisions are selected by hand and moved to the nearest package conveyor for hoisting to the 01 deck. Upon arrival at the 01 deck the boxes are assembled into palletized loads and moved by fork lift to one of several highline transfer points on the wings of the 01 deck or to the helicopter platform on the extreme after end of the ship for transfer to the customer ship via vertical replenishment.

In summary, the issue process involves random selection of materials and hand movement to the package conveyor

for the vertical lift to the 01 deck one case at a time. The cases are assembled into palletized loads on a customer basis and moved to the transfer point by fork lift. Data concerning the elapsed time and cost of alternative A can be found in Appendix A.

B. PALLET CONVEYOR AND ELEVATOR

Alternative B involves replacing the No. 2 package conveyor at frame 175 with a 9000-pound capacity pallet elevator, and replacing the No. 3 package conveyor with a 3000-pound capacity vertical pallet conveyor. Naval Ships System Command has recommended this configuration in two ship alterations for AOEs 1 and 2. Ship Alt. AOE-84 specifies a 3000-pound capacity vertical tray type conveyor at frame 196, and ship Alt. AOE-94 specifies a 9000-pound capacity cargo elevator with a 7-foot by 9-foot platform having an operational speed of 150 feet per minute (fpm). This size platform would be sufficient to transport two pallets of provisions with each cycle. Ship Alt. AOE-83 additionally calls for an increase in the ship's fork lift allowance so that a fork lift may be permanently installed (referred to as captive) in each of the levels of Hold No. 5.

---

[6] It will be assumed for alternatives B through F that those ship alterations identified in the basic assumptions have been accomplished providing the fork lift operating capability within each of the levels of Hold No. 5.

1. Loading Procedure

The loading procedure under alternative B would be significantly changed from the base case in alternative A. Pallet loads of provisions would be lifted from the pier to the 01 deck in the same manner as in alternative A. Fork lifts would also pick up the cargo from the wing of the 01 deck and move it to the pallet elevator or conveyor amidships. However, instead of breaking down the pallet at this point, the fork lift would place the palletized cargo on the conveyor or elevator for lowering to the appropriate storeroom. Upon arrival at the storeroom another fork lift would move the pallet load of cargo to its designated stowage location. This would end the loading procedure unless the particular pallet load was an item designated for non-palletized or hand stowage. Such items would be those carried in small quantities where palletized stowage would require excessive space. In this case, the fork lift would deliver the pallet load as close as possible to the position in which the item is to be hand stowed and thus minimize the manning requirements for hand stowage.

2. Issue Procedure

For those provision-line items which are stored on pallets and requisitioned by customer ships in palletized unit quantities, a fork lift in the storeroom simply would pick up the pallet load of provisions and deposit the pallet on the elevator or conveyor for hoisting to the 01 deck. A fork lift on the 01 deck would then move the pallet to

the appropriate transfer station. Thus for palletized issues of this nature all manhandling would be eliminated. However, it must be kept in mind that this consistently involves only half a dozen line items of provisions out of several hundred carried in stock aboard the AOE.

For those line items not stowed in palletized quantities or requisitioned in quantities less than palletized units, a work party would have to select the material as required from palletized or non-palletized stowage and build a customized pallet load of provisions for the customer ship. However, under alternative B the pallet load would be assembled in the storeroom vice assembly on the 01 deck as in alternative A. The assembled pallet would then be moved to the elevator or conveyor for lift to the 01 deck and subsequent delivery by a fork lift to the appropriate transfer point. If quantities being issued to one ship were not sufficient to assemble into a pallet load on any one level, the several quantities issued from several levels could be moved to the 01 deck or another level within Hold No. 5 where they would be coordinated into a single pallet load. Appendix B contains time and cost data for alternative B.

C. TWO-PALLET CONVEYORS

Alternative C involves replacing the No. 2 and No. 3 package conveyors with 3000-pound capacity pallet conveyors. This alternative is very similar to alternative B except that a pallet conveyor would be installed at frame 175 vice a pallet elevator. Appendix I provides loading-cycle time

differentials between the pallet elevator and pallet conveyor. This alternative also assumes captive fork lifts on each of the levels in Hold No. 5 as called out in the proposed AOE ship alterations.

1. Loading Procedure

The loading procedure for alternative C would be identical to that in alternative B except for the use of a pallet conveyor vice a pallet elevator.

2. Issue Procedure

The issue procedure would also be identical to that in alternative B except for the use of the pallet conveyor. Appendix C contains time and cost data for alternative C.

D. YARD AND STAY SYSTEM WITH HATCHES AMIDSHIP

The yard and stay method (also known as the "burtoning system," "married falls," "union purchase," or "union system") is one of the most commonly used methods for loading and unloading cargo with ship's gear.[7 & 8] The conventional yard and stay method is illustrated in Fig. 5. The yard and stay system consists of two cargo booms - a hatch boom rigged

---

[7] Grove, Ing. E., "Rationalizing Cargo Gear for Handling General Cargo on Ships," Ships Gear 1966, Fishing News (Books) Limited, London 1966, p. 396.

[8] Arnott, David, Design and Construction of Steel Merchant Ships, The Society of Naval Architects and Marine Engineers, New York, 1955, p. 322.

and plumbed over the hatch and the yard boom rigged over the pier.[9]

The fall ends of the hoist lines from the two cargo booms are secured to a common cargo hook. The separate hoist winches are operated in coordinated fashion to pick the cargo up under the yard boom, swing the cargo over the gunwale and other deck obstructions, until it is fully supported by the hatch boom. The cargo is then lowered into the hold. The reverse process is used for unloading the ship. Given small hatch areas so the hatch boom does not have to be re-plumbed, no heavy lift requirements, and minimum necessity for rig changes, the yard and stay system can still give faster loading and off-loading times than any other system in certain cargo operations.[10]

The principle involved in this method is that of the span. As long as the angle formed by the two hoist lines at the cargo hook remains less than 120 degrees, the strain on either hoist line will be less than, or at most equal to, the weight of the load (see Figure 6). The load refers to the safe working load of the hoist line (single whip). If the angle is greater than 120 degrees at the cargo hook, then the whip must be doubled or the quantity of cargo

---

[9] Bureau of Naval Personnel, Seamanship, NAVPERS 16118-A, 1951, p. 67.

[10] Lawrence, D. A., "Developments in Cargo Handling Techniques," Ships Gear 1966, Fishing News (Books) Limited, London, 1966, p. 413.

reduced. For hypothetical AOE provision loading, a 5/8-inch hoist line could lift a robot with two pallets of provisions on a single whip. The breaking strength of 5/8-inch diameter high quality wire rope is 16.7 ton.[11] & [12]

1. Amidship Hatches

A yard and stay system is ineffective if a hatch system cannot be installed that allows direct access to the cargo hold or storerooms. The hatches must be installed in a manner that provides good vertical access to the cargo hold, adequate width and length for the cargo gear and loads being used, and, preferably, located amidship for ease of operation in loading from either port or starboard sides of the ship. Review of AOE drawings, actual shipboard equipment configuration, and consultation with AOE design personnel at Puget Sound Naval Shipyard revealed that it is possible to install a hatch system penetrating the AOE amidship that will provide access to all storeroom levels of Hold No. 5.

The existing seven-foot by nine-foot hatch system on the port side of Hold No. 5 is too small for handling robot gear. Enlargement of this hatch system would significantly reduce useable storeroom space and present rigging strain factors if it was attempted to load the ship from the star-

---

[11] Horton, Holbrook L., Machinery's Handbook, Industrial Press, Inc. New York 1971, p. 481.

[12] Bureau of Naval Personnel, Seamanship, NAVPERS 16118-A, 1951, p. 68.

board side by yard and stay method. The rigging strain is a result of the required height of the cargo hook so the load can clear obstructions including winches and other gear on the 02 deck. Minimum clearances would require angles at the cargo hook in excess of 120 degrees when loading from the starboard side. To provide adequate operational clearances, the winch falls would have to be doubled to avoid excessive strain on the rigging. However, this would reduce the operating speed of the yard and stay system by one half which would be a significant drawback.

Installation of a cargo hatch system amidship on the AOE would be subject to several constraints if investment and installation costs are to be minimized. The width of the hatch would be limited to approximately 14 feet 6 inches, because each deck penetrated is supported by major longitudinal strength members positioned 7 feet 6 inches outboard, port and starboard, of the ship's center line. These longitudinals are large "I" beams running fore and aft which would have to be cut, moved farther outboard and redesigned to tie back into the main strength members located 7 feet 6 inches outboard of the center line in the adjacent compartments so that these support members would be continuous fore and aft throughout this region of the ship. These longitudinals also provide major strength on the outboard side, port and starboard, of the proposed hatch system. Accomplishing this design change on each deck would be a significant re-design of the ship and would involve costly

major structural modification. Therefore, consideration of an amidship hatch system wider than 14 feet 6 inches is considered infeasible from an economic standpoint.

The length of an amidship hatch would not be constrained by major strength members, but the position of the hatch system along the centerline would impact on the location of existing non-load supporting bulkheads and existing partitions and access trunks. With assistance from the design department at the Puget Sound Naval Shipyard, the optimal size and location of a hatch system on the AOE for yard and stay operations would be amidship 14 feet 6 inches in width and 12 feet 6 inches in length running from frame 178 aft to frame 183. This hatch size is large enough for a single robot measuring 4 feet by 8 feet, and the location minimizes movement and re-design of existing bulkheads, piping systems, etc. However, this location would involve the following design changes and shipboard modifications: (1) On the 02 deck the large high line winch located to port of the ship's center line at frame 183 would have to be moved aft three feet. The two outhaul winches located at frame 176 for the FAS (fueling at sea) stations Nos. 9 and 12, would have to be moved outboard three feet to starboard and port respectively. The expansion joint at frame 182 would have to be re-designed either by moving the entire expansion joint aft by 2 feet 6 inches or by designing an offset in the amidship section of the expansion joint to skirt the aft end of the proposed hatch penetration. (2) The 01 deck

would require only minor rerouting of light overhead plumbing to go around the hatch penetration. (3) The main deck would require one door relocated for the carpenter shop. (4) The 2nd deck would require the relocation of a section of a drain line which involves lightweight plumbing. (5) The partition forming the diffuser room on the 2nd, 3rd and 4th decks would require a small indentation for the cargo hatch cover. The diffuser room would lose approximately two square feet of floor space on each level. (6) The overheads and decks in the remaining compartments are clear for the hatch penetration and installation of flush watertight hatch covers. However, some deck hardening would be required around the hatch opening on each deck to provide adequate support for fork lifts and palletized cargo loads operating in the square of the hatch and in the immediate vicinity thereof.

Design personnel at the Puget Sound Naval Shipyard advise that the above design and structural changes are feasible and are not difficult. Only the re-design of the expansion joint on the 02 deck would offer much of a challenge but this, also, can be accomplished.

Hatches of the size and weight required for this operation would require mechanical opening and closing capability. Numerous hatch-closing systems are available. Closing systems which operate on electrical power or low air pressure are preferred by NSY Puget Sound designers over hydraulic systems. Hydraulic leaks in provisions storage

areas are very undesirable. The significant considerations for selecting a hatch and hatch-closing system include the capability for speed and ease of opening and closing, water tightness, simplicity in operation and reliability and economy of operation.[13]

An in-depth analysis of the various hatch systems available is beyond the scope of this study. The purpose of the above comments is to inform the reader of the complex nature of watertight hatch-closing systems aboard cargo ships.

2. Yard and Stay Booms on the AOE

The location of yard and stay cargo booms for Hold No. 5 on the AOEs 1 and 2 is dictated by the location of existing RAS "M" frames, the deck areas used for fork lift cargo handling and the space available for installation of cargo hatches into the Hold No. 5. To avoid interference with fork lift operations on the 01 deck the booms must be mounted on the 02 deck. This means that the heel of the booms would be a minimum of 28 feet from the sides of the ship. When the ship is breasted out 15 feet from the pier the horizontal distance from the 02 deck edge to the cargo pickup point on the pier is 52 feet. A boom at 45 degrees elevation, so as to avoid excessive topping lift loads,

[13] Nagel, R., Scholes, R., and Hover, P., "Progress in Hatch Cover Actuation," Ships Gear 1966, Fishing News (Books) Limited, London 1966, p. 404.

would have to be approximately 75 feet long to span this distance.

Yard and stay systems on conventional cargo ships use five-ton-capacity booms in lengths of 55 to 60 feet and, as illustrated in Fig. 5, require king posts and an array of guy lines, pendants and winches to provide support for the booms.[14] Upon review of these configuration requirements with NSY Puget Sound design personnel the following observations were made concerning AOE application: (1) The "M" frame supporting the heavy replenishment-at-sea (RAS) gear located at frame 196 could be used in the manner of a conventional king post. Minor changes in RAS rigging could be accomplished to accommodate the rigging required for the conventional yard and stay cargo booms. (2) The cargo booms would have to be heeled close to the 02 deck level to provide maximum topping lift support and would have to be stowed in a vertical position because of the horizontal distance to the RAS "M" frame at frame 174 which is only 60 feet away. (3) To minimize the cost of additional winches, for loading purposes, the two outhaul winches for the heavy RAS stations 11 and 14 located at frame 195 could be used as the main cargo winches on the yard and stay system. Re-reaving the outhaul winch line would be a simple operation and these winches are already equipped with controls compatible with

---

[14] Grove, Ing. E., Rationalizing Cargo Gear for Handling General Cargo on Ships," Ships Gear 1966, Fishing News (Books) Limited, London 1966, p. 397-398.

yard and stay operations. Only additional control stations would have to be tied into the existing system.

Heeling the cargo booms at frame 196 provides much better swing radius to the optimal hatch location than heeling the booms at frame 174. If the "M" frame at the latter location was to be used at the king post supporting the cargo booms, the tops of the booms would be at significantly different levels for loading cargo. The hatch boom would have to be elevated at 62 degrees and the top of the hatch boom would be 17 feet above the top of the yard boom. Such boom-top height differences create additional strain on guy lines and pendants. An elevation difference in the boom tops would exist if the booms were heeled to the "M" frame at frame 196 but it would only amount to approximately ten feet.

During a visit aboard the USS Sacramento the author inspected the "M" frame at frame 196 and the immediate area. This inspection revealed that two spring towers located immediately forward of the "M" frame, required for shock absorbtion on the RAS system, would constrain the swing of any cargo booms heeled at the 02 deck level at frame 196. The cargo booms must have this swing capability to be spotted over the hatch or pier. Mounting the heel of the boom at a higher level on the side or corner of the "M" frame is not feasible because this would interfere with the vertical movement of the RAS carriage. In addition, conventional yard and stay pendants secured at logical mooring positions

would interfere with fork lift and RAS traffic on the 01 deck. (See Fig. 5.)

The thought of heeling the cargo booms on top of the "M" frame was initially discarded because there is nothing to use for a king post above the level of the top of the "M" frame on which guy lines and other supporting rigging could be mounted. However, several obvious advantages to elevating the heels of the cargo booms were apparent. The additional height achieved would insure an un-impeded swing of the booms and provide greater clearance for cargo loads across the deck because of the increased height of the boom tops. The cargo booms would still be in a favorable position for using the existing outhaul winches for hoist purposes and the vertical boom stowage problem could be alleviated by stowing the booms horizontally on the top of the "M" frame at frame 173. These advantages and the inherent disadvantages of the existing AOE configuration prompted an investigation into the feasibility of utilizing the yard and stay method with a different kind of cargo boom.

3. Hydraulic Telescoping Booms

The type of boom to be considered for adoption to the AOE yard and stay installation is a hydraulic telescoping boom similar to those seen on numerous commercial mobile cranes. Many such booms have been manufactured. They telescope to 75 feet or more and have adequate lift capability at the 52-foot radius as required in an AOE installation. (See Fig. 7.) Representative units are compact, requiring

only 40 inches by 60 inches of deck space for mounting, and a clear swing radius of only eight feet for the heel of the boom, winches and integral counterweight.

The hydraulically-elevated telescoping boom requires no pendants, stays or guy lines for support as is required for the conventional yard and stay cargo boom. Also, the boom has complete swing capability with a small hydraulic motor. The telescoping capability eliminates the conventional boom stowage problem, and by telescoping the booms at different lengths equal boom top heights can be achieved while the booms are positioned at different degrees of elevation. This capability reduces rigging stress created by differing boom top heights which is impossible with conventional cargo booms.

Two telescoping booms could be mounted on top of the heavy RAS "M" frame at frame 196 and centered 21 feet outboard of the ship's center line. These booms could then provide yard and stay loading capability by positioning one boom over the hatch and the other over the pier and marrying their individual hoist lines to one cargo hook. These booms and winches could be completely controlled from a set of controls near the cargo hatch or, to provide more flexibility in operations, portable remote controls are available that the operator simply straps to his chest. Thus the operator has maximum mobility and visual observation of the loading process.

4. <u>Loading Procedure</u>

The loading procedure using yard and stay equipment and a robot is very simple and inexpensive. A fork lift on the pier places a pallet load of cargo on the robot. The winch operator engages the yard boom winch to pick up the load of cargo. After the cargo load is high enough to clear the ship's deck the hatch boom winch is engaged to swing the cargo load to a position above the hatch opening. The cargo is then lowered into the hold and the storeroom where a second fork lift removes the cargo load from the robot and stacks the palletized cargo in an assigned location or positions the pallet for hand stowage of the cargo.

5. <u>Issue Procedure</u>

The issue procedure with a yard and stay system installed aboard the AOE would not differ from the procedure described in alternative A or the procedure used in alternatives B and C if pallet conveyors or elevators were to be installed. This means that the yard and stay method would not be useable during underway operations for the following reasons: (1) The yard and stay method is not readily adaptable to issues at random from several vertical decks simultaneously. The yard and stay system can only load or unload one storeroom level at a time. Changes in the storeroom level requires the closing of the hatches on the lower levels and opening all of the hatches above the storeroom being worked. The opening of all of these hatches during operations in inclement weather could cause damage to cargo

from rain, salt-water spray, etc. (2) The length of the winch fall from boom top to the cargo load develops a significant pendulous arc. Given a hatch width of only 14 feet 6 inches as previously described and a robot eight-feet wide, the tangential function for a fall of 146 feet (from boom top to the sixth deck) allows only one degree of roll before the robot swings into the side of the hatch. This narrow margin would be intolerable when normal operating conditions frequently involve five degree rolls of the ship. With a 146-foot radius the pendulous movement of the cargo load in a five-degree roll of the ship would require a hatch system 30-feet wide. This would involve 60% of the width of the provision storerooms in Hold No. 5 and is clearly impractical from the standpoint of the storage area lost to the square of the hatch for underway operations.

If the yard and stay method was to be used underway, the only area on which the system could position cargo for movement to the helo deck or replenishment station would be on the uncovered port or starboard sections of the 01 deck between frames 175 and 195. This is highly undesireable because this is a deck area heavily used for movement of ammunition during underway replenishments, and positioning pallet loads of provisions in this area would not only interfere with ammunition movement, but the overhead lifting operation would be a safety hazard in other than calm seas.

6. Results of Yard and Stay Experiments

The author set up a hypothetical AOE yard and stay cargo operation on the Cargo Rigging Strain Demonstrator at the Naval Transportation Management School, Oakland, California, on 15 February 1974. The model is a full scale (one inch to one foot, and one pound to the ton) mock-up of a cargo ship's king posts, booms, winches, deck, hatches and gunwales. The winches are electrically operated and all loads placed on lines, booms, blocks and king posts are continuously measured electronically for stress and digitally displayed in tons. The model is also capable of inducing ship's roll, pitch and wind conditions to scale.

The purpose of the experiments was to determine if yard and stay operations on an AOE would create excessive line strain or wear and to identify control problems, effects of hatch-width constraint and list tolerances.

a. Model Constraints

Unfortunately the model could not be configured exactly like the AOE shipboard measurements required because the model scale was not as wide as an equivalent AOE model, the king posts were closer to the hatch than desired (and they could not be moved), and the cargo booms could not be extended to the length desired. However, by elevating the heel of the cargo booms, extending one boom to its maximum scale length of 48 feet and rigging through an auxiliary boom on an adjacent model the following critical dimensions were set up: (1) a boom top elevation above the deck of

52 feet; (2) a span between boom tops of 82 feet for an eastern rig, and a span of 90 feet for a western rig;[15] and (3) the hatch opening was constrained to a size of 12 feet 6 inches long by 14 feet 6 inches wide.

b. Findings

While operating the Cargo Rigging Strain Demonstrator in the above configuration with a simulated robot load of cargo, the existing configuration of the USS Sacramento (AOE 1) was reviewed on a set of drawings and selected blueprints obtained from NSY Puget Sound. Measurements and observations were taken at various stages during simulated loading cycles resulting in the following findings:

(1) Control. The winch operator, if positioned where he can see into the hatch, cannot see the pier. He would need an assistant for control of the robot on the pier. The winch operator would not be able to observe the lines on the yard and stay cargo hoist winches. If the RAS outhaul winches at frame 195 were to be used the operator's view would be cut off by the large RAS highline winches at frame 185 which are positioned between the outhaul winches and the proposed location of the hatch system to Hold No. 5. This is an important safety consideration. The winch operator should be able to observe the amount of slack on the cargo hoist winches and the manner in which the line is laying on

---

[15] The hatch boom is plumbed to the center of the hatch in an eastern rig, whereas the hatch boom is plumbed to the offshore edge of the hatch in a western rig.

the winches so that he does not engage the winches in such a manner that the line will pinch and cut itself off or create excessive line whip or strain do to rapid take up of slack.

(2) Line Wear. When loading from the port side of the ship with the boom tops elevated 52 feet above the deck, the hatch boom hoist line will not clear the top of the ship's crane located on the port side of the 01 deck at frame 183 when the robot is on the pier. If the ship is not breasted out from the pier, the hatch boom hoist line will rub on either the port or starboard railing of the 01 deck unless the robot gear is landed on an area of the pier some 28 feet from the side of the ship. This much space does not exist between the edge of the pier and the cargo warehouse or transit shed on many piers. This rubbing problem on the port crane and the 01 deck rails can be alleviated by further elevating the boom tops to 76 feet above the deck, which would be the case if the suggested hydraulic telescoping booms were to be mounted on top of the heavy RAS "M" frame at frame 196.

Regardless of the boom heights and whether an eastern or western rig is employed on the yard and stay system, the boom-top-to-boom-top span and the 14 foot 6 inch wide hatch opening presents a serious line-wear problem when a cargo load enters the hatch. The yard boom hoist line will start to rub on the hatch edge on the 02 deck when the cargo hook is only six feet below the hatch coaming. At this point, the cargo load is still eight feet above the

second deck, which is the uppermost cargo storeroom. It would be reasonable to expect that the line-rubbing problem on the hatch coaming and ship's railing could be reduced somewhat by the installation of rollers to support the line at these points. However, this is not the case. Because of the many possible combinations of boom configurations to satisfy loading requirements in different ports, the lines will not always rub the rail or hatch coaming in the same location. Therefore, a long roller or similar device would be required on each railing and additional rollers on each side of the cargo hatch. The rollers on the hatch edges would have to be several feet long to compensate for different boom-angle configurations. Consequently, the roller would be flat in nature. Supporting grooves designed in the roller would be effective only if the boom-top-to-boom-top axis were very close to being perpendicular to the plane formed by the keel and center line of the ship. This would seldom be the case. Given the distances required normally to reach cargo on the pier, the top of the yard boom creates approximately a 30-degree angle for the hoist line at the edge of the hatch. A sheave or roller cannot be too flat, or the groove too large, or not alligned with the run of the line, because it will fail to offer support for the wire rope. The result will be early failure of the hoist line resulting from the line flattening out under tension

increasing fatigue in the individual wires and strands.[16] Thus, the rubbing problem can become a significant safety factor. Early hoist line failure under heavy loads is a hazard to cargo-handling personnel. This fact also mitigates against the use of the RAS outhaul winches as hoist winches for the yard and stay system as suggested by NSY Puget Sound design personnel. Early fatigue of these lines would directly affect the safety of the primary replenishment mission of the AOE and present possible personnel and equipment hazards to ships alongside as well as the AOE in the event of an outhaul line casualty during RAS.

(3) Obstacle Clearance. With the boom top heights of 52 feet above the deck, only marginal clearance can be achieved over obstructions on the 02 deck on the AOE. The significant obstructions are the RAS control stations located at the port and starboard edge of the 02 deck at frame 187. These stations are eight feet high. The highline winches located at frame 185 on the 02 deck are five feet high. With robot gear, less than two feet of clearance can be achieved over these obstacles without exceeding a 120-degree angle of the hoist lines at the cargo hook. The highline winches do not present a clearance problem but the ship's crane at frame 183 and the RAS control station on the port side of the 02 deck would present a restriction to

---

[16] Arnott, David, Design and Construction of Steel Merchant Ships, The Society of Naval Architects and Marine Engineers, New York, 1955, p. 325.

loading cargo from the port side with the yard and stay system with the boom tops at 52 feet elevation. Several attempts were made on the model to clear an object simulating the ship's crane. It was found impossible to clear the crane without exceeding line angles of 120 degrees and, as previously explained, this would require doubling the hoist lines to safely provide adequate clearance which would significantly slow the loading operations.

If the cargo booms were mounted on top of the "M" frame thus increasing the boom top height to 76 feet above the 02 deck, then adequate clearance is achieved with a margin of clearance approaching 20 feet.

(4) Hatch Size Constraint and List. Besides creating a line wear problem, the narrow hatch on the cargo rigging model quickly validated the previously identified problem of trying to operate the yard and stay system with the ship sustaining a list. Although the model could only simulate a cargo hold of 25 feet in depth below the 02 deck, a list of 2.5 degrees put the cargo load against the hatch coaming. With a boom-top height of 76 feet, a list of 1.7 degrees would prevent a previously plumbed hatch boom from lowering the robot into the hatch. It is thus concluded that operating a yard and stay system while the ship is underway, sustaining 4 to 5 degree rolls, through a 14 foot 6 inch hatch, is virtually impossible. Operations in port are only marginally feasible if the ship's list can be maintained to less than 1.0 degree. This is an extremely close

tolerance during a loading operation.

(5) Other Rigging Problems. The 70-foot distance between the 02 deck and the 6th deck, within the hatch constraint, presents the likelihood of the married hoist lines tangling. This would be particularly prevalent with the yard and stay system rigged in an eastern rig. The yard boom hoist line is normally in a slack condition when the cargo is in the square of the hatch and this line will have a tendency to twist around the burdened hatch boom hoist line. This could not be observed on the Cargo Rigging Demonstrator which uses limp braided nylon line but persons experienced in wire rope applications in the yard and stay system agree that this twisting tendency will exist. This problem is alleviated somewhat by using the western rig which places some tension continually on the yard boom hoist line while the cargo load is in the hatch. However, this would significantly increase the line wear problem on the hatch coaming because of the increased tension on the yard boom hoist line.

7. Summary of Yard and Stay Experiments

The yard and stay experiments on the Cargo Rigging Strain Demonstrator showed that the boom top height must be more than 60 feet above the 02 deck to provide adequate clearance of cargo loads over obstructions without exceeding 120 degree hoist line angles at the cargo hook. Portable controls and additional assistance would be required for the operator to safely operate the system. The hatch width of

14 feet 6 inches is a major operational constraint because of tight list tolerances and the line wear that would occur on the hatch coaming. (See Fig. 8.)

E. SHIPBOARD CRANES

The use of shipboard mounted cranes to load cargo into or out of the hold of a cargo ship is a common application of heavy lift equipment. This application aboard the AOE could be used with an amidship hatch system as described in the previous section or simply for lifting cargo to the 01 deck as in present loading operations. For maximum flexibility of loading from either side of the ship, two cranes would be required, or a mobile crane designed with sufficient overhead clearance, while in a boom-stowed configuration, to be moved from one open wing of the 01 deck to the other through the enclosed central part of the 01 deck. The mounting of a single crane amidship would not provide adequate reach to cargo on the pier even if the crane was equipped with a 100-foot boom because the horizontal distance from the ship's center line to the cargo-handling area on the pier is up to 80 to 90 feet. Lifting cargo at an operating radius of this distance would require a boom of over 120 feet in length at a 45-degree angle of elevation so as not to exceed operational lift capability of most commercially available cranes. Additionally, during each lift cycle the crane's boom would have to be elevated to an angle of almost 70 degrees to allow adequate clearance of cargo between RAS "M" frames. A crane large enough to lift

a two-ton load at a radius of 80 feet would be in the 45-ton capacity size or larger. This is a very large piece of equipment and space is not available amidship on the 02 deck for installing such a piece of equipment. Therefore, a more feasible approach to the use of cranes with an amidship hatch system would be to install two smaller cranes, one on each side of the ship close to the edge of the 01 deck, port and starboard, to minimize required lift capacity and boom length and optimally positioned for the most rapid load cycle time; this would be a position which minimizes crane swing, boom elevation and extension from cargo pickup to lowering position over the hatch.

A second application of cranes aboard the AOE would be the use of shipboard cranes to functionally replace the mobile cranes presently provided by shore activities to swing provisions cargo aboard the ship as previously described in Paragraph A of Chapter III. This application would be operable with existing package conveyors and proposed pallet conveyors and elevators. Appendix G illustrates the potential cost effectiveness of installing shipboard cranes vice hiring mobile cranes for support from the pier. Although the cost savings based on the loading of provisions alone is not sufficient to justify procurement of shipboard cranes, an unquantifiable advantage of installing the cranes is the self-sustaining or self-loading capability that would be provided to the ship for use in undeveloped ports.

The basic advantage of cranes is the ease and speed of setup over the yard and stay and other cargo-handling methods (including conveyors, roll on roll off, etc.). A crane can be ready for loading within minutes of arrival at a pier without the time spent unstowing, rigging, spotting and plumbing booms as required with a yard and stay system.

1. Loading Procedure

The loading procedure is very similar to the steps in loading with a yard and stay system except that only one boom and one hoist line are used. A robot is also recommended to minimize personnel requirements. A fork lift on the pier would place palletized cargo on the robot. The crane would then lift the load high enough to clear obstructions on the 02 deck in the vicinity of the amidship hatch. The entire crane, boom and load would pivot or swing on the crane's turntable until the load is centered above the hatch. This centering operation may require adjustment of the boom elevation and boom length if a telescoping boom is used. The cargo load would then be lowered to the cargo hold in the ship. The cargo would then be removed from the robot by a second fork lift in the storeroom. The same steps would be repeated for each lift of cargo, including the adjustment in boom elevation and length, which would be required 1000 times for the assumed standard load. However, the crane's boom would initially be elevated in a position that would minimize these repetitive adjustments during each cycle.

The loading cycle without an amidship hatch would be identical to that described under alternative A for lifting the cargo from the pier to the 01 deck except that the ship's crane would lift the cargo vice a mobile crane.

2. Issue Procedure

Cranes, with the amidship hatch system, are restricted in the issue process during underway operations in the same manner as the yard and stay system. That is, the crane system is not adaptable to issues from several decks simultaneously as the list and pendulous arc problem prevails and there is no space available on the 01 deck on which the crane can stage cargo for transfer without interfering with ammunition traffic.

3. Constraints

The ship's list-and-roll constraint in relation to the limited 14 foot 6 inch hatch width is more of a problem with crane operations than with the yard and stay system. First of all, the yard and stay hatch boom is spotted and plumbed in the position desired, and is not moved during the entire loading operation. The crane boom is not so precisely aligned and is subject to some error and horizontal mis-alignment upon each loading cycle. This is a time consuming process and the cargo must be lowered into the hold at a slower speed than with the yard and stay system. This is to ensure that a minor mis-alignment in each loading cycle does not cause the robot gear and cargo to hang up on one of the lower deck edges. Secondly, the crane operator

has no control over the swing of the cargo as the load is lowered into the hatch. At least the yard and stay winch operator, with a western rigged system, has some control over the cargo's pendulous movement because two winch lines are attached to the cargo hook and, by applying proper tension to the yard boom hoist line, the cargo-load swinging can be limited well into the hatch opening.

To eliminate the pendulous-swing problem, it is necessary to exert the proper forces in a precise manner and limit the pendulous length from the boom to the cargo. When suspended from the crane, this distance should be as close to zero as possible. It then follows that the tip of the crane should be capable of positioning itself at the cargo. Fig. 9 illustrates a combination crane and backhoe conversion theoretically designed to handle cargo in a ship's pitch and roll environment.[17] However, a crane similar to that shown in Fig. 9, designed for the AOE, would require both of the rigid boom sections to be upwards of 90 feet in length. This would require a much larger hatch opening than is presently practical, and there is insufficient room between the RAS "M" frames on the 02 deck of the AOE to permit operation of a crane this size.

Another suggested solution to the pendulous-swing problem, list, and hatch constraints facing a crane installation,

---

[17] Winfrey, Richard C., A Review of Cargo Handling Equipment, Naval Post Graduate School, 1 October 1971, p. 20.

is the use of guides in the amidship hatch system to control the movement of the robot. Fig. 10 illustrates this concept. A similar system is used for guiding large containers into the holds of modern container ships. Such a system would allow the use of a larger robot and a smaller hatch system. A larger robot would provide increased lift capability to two pallets per cycle vice one pallet.[18]

An installation such as illustrated in Fig. 10 is not known to exist and its feasibility is an unknown factor. The author, from cargo handling experience, would anticipate the following operational difficulties: (1) The crane operator would have difficulty positioning the robot into the throat of the guides. This problem is not present with container ship loading because a large overhead gantry crane can precisely position the containers. (2) The robot would have a tendency to twist and bind in the guides if the ship began to list during the loading operation. (3) Damage to the guides would place the system out of commission. The guides, being mounted on the bottom of frequently operated hatch covers and exposed to frequent fork lift traffic, are highly subject to damage. A small push or blow by a fork lift, while maneuvering in tight quarters, could easily knock the guide out of alignment; or, worse yet, kink the guide so that the robot could not be lowered or raised.

---

[18] Suggestion made by CDR P. W. Benediktsson, staff, Naval Postgraduate School.

This is not a problem on large container ships because the guides are large, permanent fixtures within the ship and not subject to below deck fork lift traffic or other traffic fore and aft, or athwartship cargo movement below decks.

F. SIDE-LOADING TRANSPORTER

The side-loading transporter has been installed on large ships primarily for the purpose of loading baggage and other lightweight cargo. Most installations are on passenger liners.[19] The design of this equipment has many desireable features applicable to the AOE provisions-loading process. This equipment incorporates the advantages of both a gantry crane and a shipboard elevator which is useable underway as well as inport and, by its design, eliminates problems of list, roll and pendulous cargo swing observed in the yard and stay and conventional crane loading systems. Side-loading transporters are also designed for loading from either side of the ship, while requiring only one elevator shaft for access to the cargo storerooms. The basic advantage of this system is its efficiency in the limited lift required from the pier, direct traverse, and lowering into the cargo hold via the elevator shaft. (See Fig. 11.)

---

[19] Hepburn, D. and Gibson, J.B., "Developments in Side Loading Transporters and Deck Auxiliaries," Ships Gear 1966, Fishing News (Books) Limited, London, 1966, p. 389.

1. Loading Procedure

A fork lift on the pier would place a pallet(s) of cargo on the transporter platform. The platform would be hoisted to the level of the transverse passageway and the carriage and platform would then travel athwartship to the elevator shaft. At this point, the transporter platform becomes an elevator platform and is lowered to the appropriate level by the hoists integral to the carriage. A second fork lift removes the pallet of cargo from the platform and stows the cargo. The platform is returned to the pier for another load. Data concerning the elapsed time and cost of alternative F can be found in Appendix F.

2. Issue Procedure

While underway, the transporter and its platform operate in the elevator shaft in the same manner as the elevator presently installed in AOEs 3 and 4 at frame 174. The issue procedure previously described under alternative B would apply.

3. Constraints

Although designs are being developed to provide up to 20-ton lift capacity, present capability is only in the two-to-three-ton range. Present design speeds of 80 feet per minute hoist speed and 125 feet per minute carriage traverse speeds are rather slow. Another design limitation in present equipment is the boom extension capability. Installation aboard an AOE would require 107 feet of track and a boom extension of 30 feet from the skin of the ship

or an overall reach from the ship's centerline of approximately 84 feet. Existing installations are much smaller, with 70 feet of track and 17-foot boom extension for an overall reach of 52 feet from the ship's centerline.

Installation of a side-loading transporter on the AOE within the ship's present design would be very difficult. The preferred location would be between frames 174 and 177 so that the existing package conveyor trunk could be used as an elevator shaft. However, the port and starboard hull penetration by the track and transverse boom would interfere with the existing fueling stations (12 and 9) located at frame 174 - port and starboard respectively. If the track were mounted on the 02 deck, it would have to penetrate the "M" frame supporting the above-mentioned fueling stations or the "M" frame would have to be moved. This would be a significant and costly alteration. If the track were mounted on the 01 deck, the overhead clearance would be reduced so as to restrict fore and aft ammunition and other fork lift traffic. If the track were mounted on the first deck or below, the system could not be used for underway issues because the cargo would have to be double handled to another elevator or other device to move the cargo from the storerooms to the 01 deck for ultimate movement to an RAS station or to the helicopter platform.

G. FEASIBILITY OF ALTERNATIVES

To simplify the analysis of alternatives in the following chapter, it is appropriate at this time to point out those alternatives which are considered feasible and the rationale for this judgment. Although the following analysis will emphasize the feasible alternatives, those alternatives that are considered infeasible will be related to from time to time for comparison purposes. The purpose in this is that the base case (alternative A) is incapable of handling palletized loads, and the relative costs and advantages or disadvantages of the infeasible alternatives need to be kept in mind in case the peruser of this paper is considering the alternatives described herein for application to ships other than AOEs.

1. Alternative A

The use of package conveyors and complete hand stowing of the provisions cargo aboard AOEs 1 and 2, although extremely expensive, must be considered as a feasible alternative, particularly in view of the fact that this system has been operational for ten years in AOE 1.

2. AlternativesB and C

The use of a pallet conveyor or pallet elevator vice the present package conveyor is also considered feasible. The pallet conveyors have been very successful for the loading and issuing of provisions aboard ships such as the AFS which issue provisions in greater quantities historically than the AOE. The pallet elevators, six of which are

already installed aboard the AOEs 1 and 2 for handling palletized ammunition, have also proven to be successful. The AOEs 3 and 4 have such an elevator already installed in Hold No. 5 for handling provisions and it has worked satisfactorily although the elevator speed is quite slow at 60 feet per minute. The installation of pallet conveyors or elevators can be made within the present package-conveyor trunks with some minor modifications.

3. Alternatives D and E

Although alternatives D and E are quite common on conventional cargo ships, their adaption to the AOE as described in Chapter III, Paragraphs D and E, is not considered feasible. The present design and configuration of the AOEs precludes the economic installation of a hatch system compatible to the proportional dimensions of the ship and the geometric requirements of the rigging. Also, the athwartship clearance requirements for pendulous motion of the cargo is not compatible with the hatch width. Frayed hoist lines are a safety hazard with the yard and stay method and the installation of hatch guides to avoid the pendulous movement of cargo with the crane system would be a significant added design effort and installation cost of questionable value. Underway issue procedures are extremely restrictive with these systems. Because of the ship's design (a covered 01 deck), the high traffic flow and interference of staging on the wings of the 01 deck, and the inflexibility of alternatives D and E to hoist cargo out of

several storage levels of the hold in rapid succession dictate the need for additional systems just for underway issue operations.

4. Alternative F

Although the side-loading transporter combines some favorable characteristics of the crane and elevator systems, its state of development greatly restricts its application to the AOE. The logical location on the AOE for this equipment at frame 174 would significantly interfere with present replenishment traffic during underway operations and require a major redesign of the refueling station and "M" frame at frame 174. The difficulties with alternative locations of the side-loading transporter and the fact that presently designed units could not reach the cargo on the pier if the ship was breasted out as much as 15 feet, dictate the assignment of infeasibility to alternative F.

IV. ANALYSIS OF ALTERNATIVES

Direct comparison of historical AOE provision loadouts is difficult. The quantities loaded varies widely. For instance, the January 1974 USS Sacramento loading consisted of 558 measurement ton of provisions. However, only 480 ton was loaded by stevedores at Pier 91 in Seattle. The balance of the load was loaded by ship's company personnel in Bremerton, Washington. A 1968 USS Camden loading totaled just over 1500 measurement ton of provisions, 60% of which was dry provisions which were stowed partially in spaces other than Hold No. 5. Costs are also difficult to compare historically because of different methods of charging for equipment usage. Until late 1969, crane and pier services at Pier 91 in Seattle were wholly absorbed by the Naval Supply Depot Seattle as part of its fleet support mission. Following the establishment of Naval Supply Center Puget Sound in Bremerton, Washington, Pier 91 came under the operational control of Pacific Northwest Outport MTMTS. Now the Navy is separately billed for crane services, security and other management services at Pier 91 which were previously absorbed in the NSD Seattle overhead.

Besides the differences in measurement tonnage, different activities measure the provision cargo load requirements for the AOE in different terms: Short ton (2,000 pounds); long ton (2,240 pounds); measurement ton (40 cubic feet);

and bale cube (useable volume of the shipboard storeroom) are all terms employed by one activity or another to address the AOE provision load. Direct conversion of individual commodities from one measure to another is a simple operation, but a laborious task in the aggregate.

For simplicity in analysis and to avoid confusion, the analysis herein will be based on a 600 short ton requirement which converts to 1000 measurement ton of cargo, 70% of which can be loaded in a palletized configuration. The remaining 30% is required to be hand stowed because of the small quantity of the individual line items and the need to conserve stowage space.[20 & 21]

The loading computations will be based on a measurement ton because most waterfront stevedore operations and costs are measured and estimated in terms of measurement tonnage. Loading rates are expressed in terms of measurement ton per hour, per gang hour, or gang shift; and costs are estimated for loading in terms of dollars per measurement ton.

The pallet configuration for stacking two high in the AOE Hold No. 5 storerooms is limited to 42 inches in height

---

[20] Current AOE provision load requirements promulgated by Commander Service Force Atlantic is 603.6 short ton and 1008.4 measurement ton. For computation purposes in this study, the requirement is rounded to 1000 measurement ton. (COMSERVLANT INSTR. 4423.3H dated 13 April 1971.)

[21] Naval Ship Engineering Center, Addendum to Cost and Feasibility Study of Recommended Improvements to AOE Class Provisions Handling and Stowage System, 7 March 1872, p. 1-1, and 3-2.

per USS Detroit (AOE 4) message 101125Z of May 1973. Allowing a thickness of 5½ inches for a standard 40 by 48 inch pallet, a one-measurement-ton load of cargo can be placed on the pallet so that the overall dimensions would be 40 by 48 inches and 36 inches high. Of course these measurements will vary a little because of the differences in box dimensions for different commodities. However, a pallet of 40 cases of the very common #10 cans of canned fruit, vegetables or dehydrated products will stack five cases high on a pallet and fit nicely within the 40 by 48 by 36 inch parameters. Each case displaces 1.0 cubic feet, thereby providing a net one measurement ton of cargo per pallet. For purposes of computation of the loading requirements within the model used in this study, it will be assumed that a pallet consists of 40 cases, making up one measurement ton, or one pallet equals one measurement ton.[22]

Fig. 12 is a summary comparison of loading costs, savings, resource requirements and production rates for the six alternatives, A through F, assuming a 1000 measurement ton load, 70% of which can be stowed on pallets. The detailed figures for the individual systems are contained in Appendices A through F respectively. The computations were developed from data assembled and compiled for stevedore costs

---

[22] If the reader wishes to deal in short tons, the assumed pallet with an average weight of 30 pounds per case or box, provides a pallet weight of 1200 pounds or 0.6 short ton.

and requirements, Appendix H, and equipment and handling evolution times and capacities computed in Appendix I. Appendix I reflects the data of subevolutions which, when combined in different combinations, make up the alternative systems. The details of data source and computation are explained in the front of each appendix.

To compute the capacity and cost of a given alternative system, the system was divided into its several cargo handling evolutions involving different equipments. Stowage was constrained to one stevedore gang and/or one fork lift in the hold per crane, elevator or conveyor available to feed cargo into the hold. Then, combinations of fork lifts, cranes and other components of the system were selected for a balanced capability that either maximized the stowage rate for the given crew or approached practical operational constraints such as the congestion created on the 01 deck between frames 174 and 196 if more than four fork lifts or more than two cranes were to handle a cargo in this area. The logic flow for determining the capacity of the alternative systems is illustrated in Fig. 13.

A. COST SAVINGS

One of the major considerations in evaluating any proposed system is whether there are cost savings if the existing system is replaced. This section will compare the cost factors of loading provisions under the several alternatives as computed by the model and then project the savings of the

feasible alternatives in terms of present value savings over alternative A over a remaining assumed life for the AOE of 15 years.

1. Comparison of Alternatives

The model computes a loading cost for stevedores and equipment under the base case (alternative A) of $34,345.00 for a 1000 measurement ton load, or $34.345 per measurement ton. This is conservative when compared to historical records for AOEs 1 and 2 as illustrated in Fig. 14. However, the figures illustrated in Fig. 14 include overtime charges in the case of the 1973 and 1974 AOE 1 loadings plus equipment malfunctions, late arrival of cargo and other delays which are not considered in the model.

All of the alternative systems have a lower loading cost than alternative A because of the capability of these systems to load less labor intensive palletized cargo (which is beyond the capability of alternative A presently in operation on AOEs 1 and 2). It is interesting to note that alternatives B through F all have average costs per measurement ton generated by the model within a $1.75 range although the individual costs for palletized cargo (or hand stow cargo) vary by as much as $3.00 to $4.00 per ton. Also, within each system the cost of hand stowing cargo is significantly higher than the cost of stowing palletized cargo. The least costly system for loading the hypothetical 1000 measurement ton of cargo is a tie between systems B and C. This is the result of the limited capability of the

mobile cranes required to lift cargo from the pier to the 01 deck. Although the average cost per ton for alternatives B and C is not significantly lower than some of the other alternatives, the cost per ton for stowing palletized cargo in alternatives B and C is significantly (48%) lower than the average of the other alternatives (D through F). On the other hand, alternatives B and C have an average cost for hand stow cargo 29% higher than alternatives D through F. More will be said about the load mix of palletized and non-palletized cargo in Chapter V, Paragraph C.

2. <u>Projection, Escalation and Discounting</u>

Assuming an equivalent of three loadings per year, the model reflects an annual savings in stevedore costs alone for alternatives B or C amounting to $81,266.00. Projecting this value 15 years into the future at a conservative 6% per annum inflation rate balloons this savings into $183,742.00 per year in 1989. The present value of the sum of these annual savings discounted to 1974 at the D.O.D. prescribed 10% annual discount rate amounts to $908,569.00. This figure is an indication of the current level of investment that could be made in alternative B or C, the value of which would be recovered over the remaining 15 years of the AOE's life if the assumptions in the model hold. If the AOEs 1 and 2 are operated for more than 15 years, these accumulated savings would amount to more than $908,569.00, warranting an even larger present investment in alternative B or C.

B. MANPOWER ANALYSIS COMPARISON

1. Loading Provisions

Alternatives B and C require the same number of stevedores, twenty four for palletized stowage operations and thirty one stevedores during hand stow operations. This includes stevedore personnel on the pier and the 01 deck as well as two gangs stowing cargo in Hold No. 5. One gang is required for each conveyor or elevator. This is a 28% decrease in manning over alternative A which actually employs three hand stow gangs. Because of the higher capacity of the equipment in alternatives B and C, fewer people are required to stow more cargo per hour (palletized and hand stowed) than can be accomplished with alternative A.

The numbers of stevedores required in alternatives B and C is more than twice that required by the infeasible alternatives D through F. Although the hand-stow capability per gang hour is equivalent between these systems, alternatives D through F can employ only one gang at a time vice the two gangs which can be simultaneously employed in alternatives B and C. The smaller number of men required for alternatives D through F give them a favorable cost advantage for hand-stow cargo. However, the productivity of the gangs in handling palletized cargo is limited by the equipment capability in these systems.

2. Issues and Consolidations

Insufficient data is available to measure manpower requirements for underway evolutions with any precision

approaching that accomplished herein for loading operations. The underway evolutions of issues and consolidations vary significantly in size and complexity and, unlike large load-outs, may be handled with widely varying numbers of personnel depending on how many men are available, what other shipboard operations are going on simultaneously and the urgency of the situation. Getting freeze cargo below decks is more critical than striking down bales of rags or other non-perishable material on a warm day.

Fig. 15 is the author's educated guess at shipboard manning requirements to issue 150 measurement ton of provisions to three ships during a four-hour replenishment rendezvous. The only obvious manpower savings observed in alternatives B and C over the present system is the elimination of personnel required to build pallet loads of provisions on the 01 deck. However, this function is simply relocated in the storeroom for less than pallet-load issues. Possibly a man is gained from each of the palletizing crews on the 01 deck with alternatives B and C, assuming that it will take fewer people to select material and build the pallet in the storeroom vice selecting material, moving it to the 01 deck and palletizing the provisions. USS Detroit (AOE 4) message 101125Z May 1973 reports that four to five manhours per destroyer type ship is saved by having the ability to build pallets in the immediate vicinity of the stowed provisions.

Significant manpower savings, 50% or possibly more, can be achieved in issuing full pallet loads of material from the storeroom with alternatives B and C. However, it must be remembered that very few line items are issued in pallet size quantities. The vast majority of issues will still require selection of numerous line items at random and assembling them into palletized units for issue to customer ships. This is a labor intensive process and the presence of palletized materials handling equipment cannot be expected to reduce the manning requirement for this portion of the issue evolution. The stowage of cargo on pallets in the storeroom may, in fact, make the process of random selection and building of pallets slower, more difficult and create additional manning requirements that are not necessary to accomplish this task from storerooms which are presently filled with all hand stow cargo.

If cargo received during consolidations is palletized in a manner compatible with the AOE storage plan, significant shipboard manpower savings could be accrued. But, if the cargo is not palletized in the proper manner and has to be repalletized correctly, significant increases in manpower requirements would be experienced. Consolidations between Mobile Logistic Support Force ships which effectively minimize personnel for material handling requirements can only be achieved if palletization of provisions is standardized. USS Detroit has experienced a 40% savings in manpower on "major consolidations, CV UNREPS (Aircraft carrier

UNderway REPlenishmentS), and loadouts as a result of the ability to breakout/stow dry provisions on pallets."[23]

C. EQUIPMENT REQUIREMENTS COMPARISON

Alternatives B and C, besides the initial investment in pallet conveyor(s) and/or pallet elevator, would require an increase in the number of fork lifts aboard the AOE. This could amount to as many as five additional fork lifts, or an additional fork lift on each level on which palletized cargo is to be stowed. If all the cargo on a given level is to be hand stowed, a pallet jack capable of loading or removing pallet loads to and from the pallet conveyor or elevator would be sufficient.

Under alternative C, the fork lifts would be captive to the space because the 3000-pound capacity conveyor is not capable of moving a fork lift between decks. Electric fork lifts would require battery-charging outlets on each level, also increasing the initial investment.

Naval Ship Systems Command's approach to alternative B includes the assignment of captive fork lifts to each level of Hold No. 5 on which palletized provisions would be stowed. This would not be necessary if the elevator has sufficient size and capacity to move the fork lifts from one level of the hold to another. If this were the case, three fork lifts in the storerooms should suffice. One fork lift

---

[23] USS Detroit message 101125Z May 1973.

for each crew handling cargo in the storerooms would be required. For instance, two crews issuing cargo and building palletized loads would each require a fork lift and an additional man breaking out full palletized loads at the same time on a separate level would require a third fork lift.

D. ELAPSED TIME COMPARISON

The cost of holding a commercial cargo ship at a pier beyond a reasonable time to load or unload the assigned cargo can become a very costly item, easily running ten to twenty thousand dollars per day for ships which are much smaller than an AOE. An appropriate value to assign to the AOE as the cost of having the ship out of operation is not available; however, it might be very interesting to see what charges per day are received for a commercial ship of equivalent tonnage.

Of all the alternatives considered, alternatives B and C are far and away the fastest systems for loading out the provisions cargo aboard the AOE as determined by the model. These two systems are constrained by the same supporting effort of mobile cranes and thus have identical total re-lapsed times. The impressive statistic in comparing total elapsed times is that alternatives B and C are three times faster than alternative E which is in distant third place. The elapsed time achieved by alternative B can only be achieved with the cargo elevator operating at a speed of

150 feet per minute as in the model. The present 60 feet per minute speeds on the cargo elevators on AOEs 3 and 4 is unsatisfactory and use of elevators at this speed would clearly make alternative C the preferred choice on the basis of total elapsed time.

E. INTEGRATION OF ACTIVITIES

The discussion of the infeasibility of alternatives D through F in Paragraph G, Chapter III, pointed out some of their conflicts with the movement of ammunition and other replenishment traffic on the 01 deck. Unfortunately, the 01 deck area between the two existing package conveyors servicing Hold No. 5 is the major athwartship cargo-transfer passageway in the after half of the ship. With two of the most heavily used highline transfer stations immediately aft of this area, and all of the ammunition magazines forward of this area, this passageway has a heavy load of cross traffic during underway replenishment operations. Any handling of cargo in this area which can be avoided should be eliminated so as to improve traffic flow.

Under alternative A, the individual boxes of provisions must be palletized in this area after they are hoisted from the storerooms in Hold No. 5. This operation on the 01 deck is eliminated with alternatives B and C because the boxes could be palletized in the storerooms. As soon as a pallet of provisions arrived at the 01 deck on the pallet conveyor or elevator, the pallet could immediately be picked up by a

fork lift and moved to the appropriate highline transfer station or to the helicopter platform. Even if a fork lift was not immediately ready to move the provisions from the pallet conveyor or elevator the cargo would be out of the way in a protected enclosure where it would not interfere with fork lifts moving ammunition and other supplies.

F. PRODUCT QUALITY

The principal attributes of quality in provisions issues to fleet ships involves the physical condition of the package after multiple handling, the physical condition of the contents after exposure to environmental factors, and the accuracy of the documentation and cargo selection to meet the customer's requirements.

Present operating conditions under alternative A has caused mechanical damage to containers and packaging. USS Camden has reported significant problems with six-gallon milk cartons which will not stand up under the multiple handling necessary for each container processed through alternative A. Ships that can handle the same containers in palletized loads do not experience the same problem.[24]

The major quality-control problem for Mobile Logistic Support Force Ships is how to minimize the time that frozen food is exposed to ambient temperatures frequently reaching

---

[24] USS Camden letter AOE2:JAP:dp, 4400, Ser 12, 6 JAN 1974, to Commander Service Group Three, Subject: Mobile Supply Support Cruise Report, p. 3.

70 to 90 degrees fahrenheit on the weather deck. Present constraints in issues, using Alternative A, require the pre-staging of cargo in advance of scheduled replenishment rendezvous. Although frozen food may be broken out last, the slow strike-up capability of the existing package conveyors would require in excess of four hours for a 30-measurement ton breakout. Exposure times during large consolidations are even more critical where the exposure time on the transferring ship is added to the exposure time on the AOE resulting from the slow strike down process under alternative A.

The capability offered by either alternative B or C minimizes the exposure problem for frozen foods and the mechanical damage to individual boxes. It is true that if a pallet load is damaged, many boxes may be involved; but the fact that the load is palletized minimizes mechanical damage to individual boxes and also conserves temperatures in frozen foods as well as protecting boxes from inclement weather.

If the initial loadout is conducted according to the ship's stowage plan, it should be just as easy to make accurate breakouts from hand stowed or palletized cargo in the storerooms. However, during operations and consolidations, cargo is issued and is added to the storeroom. Sometimes more cargo is received than can be handled, thus creating stowage problems. Accurate control and accounting under these conditions in a hand-stowed storeroom becomes increasingly difficult. The storeroom with cargo stored on

pallets in standard quantities contributes to better control and accuracy and, ultimately, to better quality in the accuracy of the customer's breakout. Thus, palletization contributes to the quality of the customer's breakout and favors alternatives B and C over alternative A.

G. STRUCTURAL CHANGES

Alternative A requires no structural changes because it is already installed in AOEs 1 and 2. Alternatives B and C require modification of the existing package conveyor trunks located amidship at frames 174 and 196. The trunks would have to be enlarged to accommodate the larger pallet conveyor or elevator. These equipments would also require slightly larger machinery spaces than are presently used by the package conveyors in alternative A. In addition, a fork lift battery charger would have to be installed with outlets in the storeroom spaces. With alternative C, a total of five outlets are required - one for each fork lift or pallet jack captive to each level. Alternative B could be employed with no fork-lift-charging requirements in the storeroom if the elevator is of sufficient size and capacity to lift the fork lifts to the main deck or the 01 deck where battery charging outlets are presently installed.

The structural changes itemized in the basic assumptions (Chapter I, Paragraph F.4) must also be accomplished to provide fork lift capability in any of the storerooms in Hold No. 5. However, these changes would be required regardless

of which alternative was chosen to provide palletized capability in the storerooms.

The infeasible alternatives, D through F, all require significantly more structural changes than alternatives B and C in the form of amidship hatch systems, installation of new booms or cranes, or the even more complex side-loading transporter.

H. SAFETY

Palletized handling and storage possesses several safety advantages over hand-stowed cargo. First of all, the lifting and handling is done primarily by specialized powered equipment thus avoiding frequent personnel injuries such as strained backs, bruised legs and feet from dropped boxes, and other injuries aggrevated by the fatigue of handling large quantities of cargo in a minimum of time. Palletized cargo also provides for safer storeroom conditions. The large palletized loads are easy to stack with a fork lift and are much more stable than tall stacks of hand-stowed cargo in the AOE which must be randomly accessible for issues. The AOE random-issue requirement precludes hand stow of cargo in a manner that would optimize stability of the stacks of cargo in each storeroom.

Comparison of the several alternatives for palletized loading would favor first, the infeasible side-loading transporter which effectively eliminates the crane-lifting operation and fork lift traffic on the 01 deck. By

providing a continuous-movement vehicle from the pier to the storeroom (which eliminates pendulous motion and minimizes fork lift handling while providing the same safety as an elevator), the side-loading transporter is the top safety candidate.

Alternatives B and C are considered safer than the infeasible alternatives, D and E, because cargo is lifted by crane only to the edge of the 01 deck instead of across the deck. Although alternatives B and C do require an additional fork lift-handling evolution on the 01 deck, the author considers this safer than the possibility of dumping a pallet load of cargo down the amidship hatch should the robot gear strike the edge of the hatch or catch the edge of a deck and tip over because of a small pendulous swing within the hatch. This problem would be only slightly less prevalent with alternative D than with alternative E because alternative D has two hoist lines to the cargo hook providing some additional control. However, alternative D would experience undesireable line wear on the edge of the hatch which could lead to very unsafe handling conditions over the pier.

Alternatives B and C possess almost identical safety features. A slight advantage might be given to alternative C. In the event that a safety device malfunctioned on an access door creating a situation where an individual or object might fall into the conveyor or elevator shaft, the fall into the elevator would be unimpeded for a distance of

60 feet if the elevator was situated at the sixth deck. A pallet conveyor, on the other hand, with platforms mounted every ten feet within the shaft would limit such a fall to, at most, six to eight feet.

I. OPERATIONAL RELIABILITY AND CAPABILITY

Shipboard personnel on the USS Sacramento and USS Camden reported maintenance problems with both the package conveyors and shipboard cranes. The author also experienced frequent package conveyor malfunctions on the USS Sacramento during the November 1966 loading.

The cargo officer on the USS San Jose (AFS 7) reported to the author that the pallet-conveyor system installed on the San Jose had proven to be extremely reliable as was the elevator system on the same ship, but the latter was extremely slow. The USS San Jose also has an 85-pound package conveyor system similar to that installed aboard the AOEs. Although this system on the AFS 7 does not handle nearly the volume that the package conveyor on the AOE is required to handle, USS San Jose personnel stated that the package conveyor is somewhat less reliable than the 3000-pound capacity pallet conveyor system.

A 5 March 1974 letter (in response to an inquiry from the author) from the Kornylak Corporation (which manufactured the pallet conveyor system on the USS San Jose as well as the package conveyor system on the AOEs) reveals that Kornylak has never constructed a 3000 pound vertical pallet

conveyor with a lift of 60 feet as required for installation in the AOEs at frame 174 under alternative C. The largest pallet conveyor manufactured to date had a vertical lift of 48 feet. However, Kornylak engineering personnel did not think that a conveyor of 60 feet vertical lift would present any problems.

The reliability of the infeasible alternatives leaves many questions unanswered. Information could not be found concerning the reliability of side-loading transporters. Although shipboard cranes have proven to be quite reliable, in the author's experience, aboard commercial cargo vessels, the existing units aboard the AOEs have proven to be unreliable. Engineers familiar with the AOE crane problem attribute it to several causes, the most predominant being the lengthy underway periods during which these cranes are exposed to the marine environment and seldom operated. The yard and stay loading method is very reliable using conventional booms and equipment aboard commercial cargo ships. No data could be found discussing the reliability of telescoping booms used in yard and stay systems as suggested in alternative D.

The capabilities of all the alternatives in terms of lift capability is adequate for loading provisions. However, none of the feasible alternatives can provide the AOE with a genuine self sufficient loading capability. As long as the AOE is loaded in ports where the capability exists to place mobile cranes alongside the ship, this will not

present a problem. If it is ever found necessary to load provisions aboard the AOE in a port where these services are not available, the AOE is seriously handicapped because the existing cranes on board have limited reach (40 foot boom) and are too slow to be effective in loading large quantities of provisions.

V. CONCLUSION

Chapter IV compared the several alternatives in accordance with previously selected criteria. Although three of the alternatives were found to be infeasible in Chapter III, the author elected to relate their major advantages and disadvantages to the feasible alternatives in Chapter IV. A summary of the analysis for the feasible alternatives will now be made including a sensitivity analysis of the basic assumptions and specific recommendations will be suggested.

A. QUANTITATIVE SUMMARY

Cost savings for alternatives B and C, as produced by the model, amounted to $81,266.00 annually over alternative A which was the remaining feasible alternative. Projecting this savings over a 15-year remaining life for the AOE, assuming a conservative 6% inflation rate, and discounting at 10% to obtain the present value of these savings provides $908,569.00. If the current investment outlay for alternatives B and C is less than this amount, the selection of either alternative could be justified on an economic basis.

Manpower analysis shows alternatives B and C to require approximately the same number of people as alternative A for small underway issue operations. Large volume loadings, consolidations and issues to aircraft carriers where palletized loads predominate allow alternatives B and C to be much more effective than alternative A. Such transfer of

cargo results in as much as a 50% or more reduction in required men assigned. Production per man-hour is also greater with alternatives B and C thus greatly reducing the overall cargo-handling effort if the material is palletized.

Alternative A requires no additional equipment but alternatives B and C require additional fork lifts as well as the pallet conveyors or pallet conveyor and elevator. If the pallet conveyors and elevator have equivalent investment costs for procurement, installation and maintenance, and, if the elevator has the 150 feet per minute speed required and the capability to move fork lifts between decks, then alternative B is cheaper than alternative C. This is because fewer fork lifts would then be required for alternative B and fork lift battery-charging outlets would not be required in each level of Hold No. 5 as in alternative C.

Alternatives B and C require only 29% of the time (in the model) required for alternative A. The total elapsed times for alternatives B and C are identical because of the lift capacity of supporting mobile cranes on the pier. If additional crane capacity could be provided in a practical manner, alternative C could theoretically achieve a shorter elapsed time than alternative B assuming that the load consists predominately of palletized cargo.

B. QUALITATIVE SUMMARY

Alternatives B and C are equally effective in minimizing cargo traffic flow and congestion between frames 174 and 196

on the 01 deck. Alternative A requires some of this space to assemble palletized loads and cannot avoid continually occupying a portion of this space with personnel, pallets and cargo.

Alternatives B and C both offer the advantages of palletized handling in terms of personnel safety, limiting damage to cargo and providing protection to cargo from ambient termperatures and weather. Alternative A requires excessive hand movement of cargo contributing to fatigue and personnel injuries. Palletized loads also provide more stable stowage and contribute to better stock and issue control.

No structural changes are required by alternative A. Both alternatives B and C require some enlarging of the existing package-conveyor trunks to accommodate the pallet conveyors and elevator. If the pallet elevator is capable of moving fork lifts between decks in Hold No. 5, then alternative B would require less installation of fork lift battery-charging equipment.

Alternatives B and C avoid the interference created on the 01 deck by alternative A, and reduces manhandling of cargo, presenting a safer materials-handling situation. Alternatives B and C offer almost identical safety features with a slight advantage to alternative C in the event of the failure of an access door safety device. The design of the pallet conveyors in alternative C could limit a serious fall which could not be accomplished in the elevator shaft.

The package conveyors in alternative A have a poor reliability record and limit cargo movement to approximately six ton per hour. The equipment in alternatives B and C have proven to be quite reliable and can move many times more cargo in palletized loads than can be achieved by alternative A. Each individual pallet conveyor or elevator in alternatives B and C can double the capacity of one package conveyor in alternative A when it comes to loading hand-stow cargo.

C. SENSITIVITY OF ASSUMPTIONS

The basic assumptions made in Chapter I-F will now be analyzed to illustrate the effects of their variance upon the findings of this study and the data developed within the model.

1. Operational Life

A 15 year remaining life for the USS Sacramento would take the ship to 25 years of age and the USS Camden to 22 years of age. Since most auxiliary ships of the Mobile Logistic Support Forces (as well as the remainder of the Navy) have been operated for 25 years and, in many case longer, the 15-year figure is considered to be quite conservative. Continued operations past a 15-year horizon would increase the potential cost savings of adopting a palletized handling system. Fig. 16 illustrates the effect of calculated savings as a function of time and the associated error in estimated savings.

2. Scenario

Conversations with planning personnel at Commander Service Force Atlantic and Commander Service Force Pacific Headquarters, Service Group One, and, also, personnel aboard AOEs 1 and 2, reveal no planned or anticipated role change for the AOE.

3. Standard Provision Load

The quantity of provisions loaded aboard the AOE fluctuates with quantities ranging from 500 to 1300 measurement ton. Loads exceeding 1000 measurement ton create a requirement for some provisions to be stowed in spaces other than Hold No. 5. Palletized stowage for 750 short ton may require as much as 230 pallets to be stowed in ammunition or other spaces suitable for palletized stowage.[25] This fact will not significantly change costs generated by this model however because the same crew size and type of equipment can accomplish this function as is used in alternative B except that the elevators are somewhat slower. All of the elevators in the ammunition spaces are capable of handling two pallets at a time, and some of the spaces are served by two elevators. The amount of provisions that must be stowed in spaces other than Hold No. 5 will depend on the final storeroom configuration and stow plan.

---

[25] Naval Ship Engineering Center, Addendum to Cost and Feasibility Study of Recommended Improvements to AOE Class Provisions Handling and Stowage System, 7 March 1972, p. 3-2.

Because the loading is accomplished with fixed crew sizes based on whether the cargo is hand stowed or palletized, there exists a direct cost volume linear relationship. Fig. 16 reflects the range of cumulative savings to be expected with quantum reductions in standard load requirements.

4. Labor and Equipment Costs

Fig. 17 illustrates a range of increased labor costs based on overtime requirements ranging from one to six shifts on alternative A and up to 100% overtime for alternatives B and C. This data would also depict stevedore rate increases for standard time. The significant factor is that alternative A is much more sensitive to labor rate changes and, as a result, total costs for this system rapidly accelerate with increased labor costs. On the other hand, if loading was to be accomplished in a foreign port with rates 50% lower than those currently paid in Seattle, Washington, alternative A's total cost would be greatly reduced. However, alternative A's total cost would still exceed the total cost of alternatives B and C at the higher Seattle rates. Alternatives B and C, being equipment dependent, are very insensitive to labor rates. The equipment rental charge is only 6% to 8% of total cost. Even if this cost doubled, it would not greatly affect the total cost of loading the ship; nor would it warrant investment in a shipboard crane to replace the mobile cranes on the pier. Although there may be many other reasons justifying the addition of crane equipment aboard AOEs 1 and 2, life cycle accumulated

savings from cost avoidance of renting a crane just for provisions loading is not cost effective. See computations in Appendix G.

During the past eight years stevedore labor rates have escalated at an average of 8% per annum. A one-year jump of 16.7% was experienced between 1972 and 1973. Therefore, the 6% escalation used in Appendix G to compute accumulated savings of alternatives B and C over alternative A is conservative and tends to understate total savings.

5. Ship Alterations

The several actions itemized in the basic assumptions to be accomplished in proposed ship alterations are subject to conventional budget constraints. However, the accomplishment of these alterations is necessary to be able to operate fork lifts and handle palletized cargo in Hold No. 5. If these alterations are not accomplished there is no object in trying to install pallet conveyors or pallet elevators.

6. Robot Gear

The use of a robot eliminates the need for four stevedores performing the function of "sling men" and reduces an 8-hour shift cost by $356.00. This amounts to a saving of $761.00 per loadout under alternatives B and C. Robot gear reduces alternative A loading cost by $2,595.00. Robots are simple to design and construct. Weighing some 1200 to 1500 pounds and representing an investment of $3,000.00 to $4,000.00 at the most, this equipment pays for

itself in two to four years. If robot gear is not used, the additional charge represents only 7% of the alternative A cost and 10% additional cost for alternatives B or C.

7. Annual Volume

Paragraph 3 above speaks to load size. The assumption of a 3000 measurement ton annual volume is sensitive in the model. A major reduction in this quantity will have the same effect as several small loadouts which was previously discussed. For instance, a 50% reduction effectively reduces accumulated projected savings for alternatives B or C by 50% - from $81,266.00 to $40,633.00 annually. This amounts to $454,285.00 over a 15 year horizon vice $908,569.00.

8. Issue Policies

A significant change from current requisitioning and issue procedures for provisions is not likely. Issuing provisions on a "push" basis, based on standard loads for given periods and on crew size, is not compatible with present supply policies. Push procedures could also result in overstocking, waste and low morale because the ability for the individual ship to tailor its menu to the crew's particular likes and dislikes would be seriously undermined. Flexible menu planning within each ship is a major contributor to good morale aboard Navy ships.

9. Regular Time Stevedore Rates

The loading of the AOEs in Seattle normally involved one or more overtime shifts because of a tight

loading schedule. Therefore, the total costs reflected by the model can be considered conservative as they provide no overtime adjustments, penalty or other delay charges. Fig. 17 illustrates the effect overtime has in accelerating costs, particularly on alternative A.

10. Other Sensitivity Analysis

The model assumed that 70% of the 1000 measurement ton load would be stowed on pallets by those systems that could handle pallets. Fig. 18 illustrates the relative sensitivity of system total cost to the percentage of palletization. Alternatives B and C are quite sensitive to this factor; however, alternative A can only handle hand stow cargo. Alternatives D through F are illustrated for information purposes only since they have been determined to be infeasible. Fig. 19 illustrates the range of total costs generated by the model assuming various combinations of hand stow and palletized cargo in increments of 10% and ranging from all hand stow cargo (0% palletized) to 100% palletized. It should be noted that the highest cost in systems B and C are experienced with all hand stow cargo but the total cost experienced is only 47% of the total cost of alternative A for handling the same load. Fig. 20 relates the percentage of palletization and load size under alternatives A, B and C to the total elapsed time. For alternatives B and C the elapsed time is more than doubled when all hand stow cargo is handled vice the assumed base case of 70% palletized. However, even this longer elapsed time for alternatives B

and C is significantly shorter than the 7.29 shifts required by alternative A.

D. RECOMMENDATIONS

If the pallet elevator and pallet conveyor represent equivalent investments, the author recommends adoption of alternative B for the provisions-handling system on the AOE if the new cargo elevator can be designed to move a fork lift between levels in Hold No. 5 and achieve an operational hoist speed of 150 feet per minute with two pallets of provisions. If these two conditions cannot be met, then it would be recommended that alternative C be adopted. However, since a 3000 pound capacity pallet conveyor has never been installed aboard ship with a 60-foot lift requirement, it is further recommended that the new conveyor be thoroughly tested in a realistic mockup prior to installation.

1. Sequence of Implementation

Delays in accomplishing conversion to a palletized handling system reduces the cost savings that can be accrued; but, in the current budget environment, funding may be constrained necessitating incremental implementation. In this case, the following sequence is suggested:

a. Refrigerated Spaces

The sensitivity of freeze cargo to ambient temperatures and the resulting deterioration in quality should receive first priority. Excessive thawing and inadequate protection can create a health hazard. Therefore,

palletized handling capability in this area is recommended as first priority. This would involve accomplishing ship alteration AOE 96 to permit palletized handling in the existing refrigerated spaces and the installation of a pallet conveyor at frame 196 which would replace package conveyor No. 3. Temporary access of fork lifts to the refrigerated spaces could be accomplished by lowering the equipment through the small hatch system on the port side of the dry-provisions storerooms at frame 178. Doorways could be enlarged between the dry and refrigerated compartments on each level to admit the fork lifts to the refrigerated spaces. The fork lifts would be captive to these spaces until an elevator could be installed at frame 174, and battery charging outlets would be required on the 2nd, 3rd and 4th decks in Hold No. 5.

b. Elevator

Assuming alternative B is adopted the second recommendation would be to install the elevator at frame 174 to provide greater hand-stow capacity for dry provisions and added flexibility of moving fork lifts between decks. Although the decks in the dry-provision spaces are not yet prepared for fork lift operations, a central area could be improved so that a fork lift could unload pallets from the elevator for hand stowage and place assembled pallets on the elevator during issue operations.

2. Equipment Specifications

The author's research and experience with the AOE provisions-loading problem has revealed the need for specific emphasis in the following equipment specification areas:

a. Deck Covering

Deck plates and gratings must be easily removable for routine cleaning as well as suitable for fork lift operations. Sharp edges or any other feature that will tend to cut or shred fork lift tires is unacceptable.[26]

b. Fork Lifts

Fork lifts, particularly if they are going to be captive to the storeroom, must be reliable with a long mean time between failures. If the ship does not have the flexibility of exchanging fork lifts between decks during underway operations, the loss of the use of a fork lift can seriously set back scheduled operations geared to palletized handling. Fork lifts should also be selected for compactness so they can be moved from space to space without folding or removing any component of the vehicle.

c. Elevator

Any pallet elevator installed in the No. 5 Hold should have an operational speed of 150 feet per minute with two pallets of cargo. The elevator should be designed with sufficient platform space, access door and lift capability to permit moving of fork lifts from level to level. If

---

[26] USS Detroit message 101125Z May 1973.

overheating of hoist motors presents a problem when lifting a fork lift, it is suggested that a hoist with two speeds be installed - one speed of 150 feet per minute for handling cargo and a slower speed for handling the heavier fork lifts.

3. Future Ships

A final recommendation concerns the design of future ships. Many economies in materials handling can be achieved through palletization and other forms of unitized materials handling. Increased mechanized handling is desirable from the point of rapid issues to fill customer requirements and reducing high labor costs. This applies to all auxiliary ships, and the principal of mechanized materials handling can be applied to all ships including the smallest combatants. The main point is that the concept of handling unitized cargo must be incorporated in the ship's characteristics and specifications for each and every cargo handling evolution. The author's experience in this study leads him to believe that the concept of life cycle cost must be applied in the area of materials handling in ship design vice the concept of designing to cost. This is one of the areas where a small additional investment during the design and construction of the AOE (and many other ships) could have significantly reduced life cycle material handling costs.

APPENDIX A

LOADING TIME AND COSTS

Appendices A through F summarize system production capacities and cost data, for alternatives A through F respectively. Under "loading", the subgroup equipment and personnel are summarized that make up the particular alternative system listed. The quantity of equipment or subgroups of stevedores is indicated in the second column, and their respective cargo handling capacity is recorded in the third column. These capacities are taken directly from the appropriate subgroup in Appendix I, and total capacity is constrained to the lowest of the several subgroups as spelled out in the logic sequence in Figure 13 and Table I. Additional fork lifts or cranes are added where the additional capacity complements handling and stowage of the subgroups working in the hold.

Total elapsed time is calculated on the basis of the assumed 1000 measurement ton load as a function of the constrained production rate.

The "personnel and equipment costs" for each alternative is developed by identifying the appropriate subgroups from Appendix H that make up the respective alternative system. The appropriate subgroups may be identified in Appendix H by referring to the subgroup alpha code in the second column. The number within the parenthesis in the second column identifies the quantity of that subgroup employed.

The cost per day for a given subgroup is the average daily cost listed in Appendix H for that subgroup, multiplied by the quantity in parenthesis in the second column. Each of the cost per day figures is then multiplied by the number of elapsed shifts computed for the particular cargo type (hand stow or palletized applicable to the respective system). These products are then summed to obtain the total cost for stowing the particular type of cargo with that system. The appropriate shift factor is recorded in parenthesis in the last column. After the total shift cost of each cargo type is computed, thus reflecting the cost for loading hand stow and palletized cargo, these two totals are combined to find the total cost for loading the 1000 measurement ton load with the particular system.

The average cost per ton is simply the total cost divided by the 1000 measurement ton, the size of the load. Following the basic assumption of three loads or equivalent per year or deployment, the total cost is multiplied by 3 to identify the annual cost.

ALTERNATIVE A LOADING TIME AND COSTS
(EXISTING SYSTEM 100% HAND STOW)

LOADING

	Equip. Qty.	Stow Cap. M.T./Hour	Constrained Stow Capacity
Fork lifts on Pier	3	112.5	
Mobile Crane Pier	1	57.4	
Ship's Crane Ops.			
Crane	1	7.8	
Fork lift 01 DK	1	44.1	
Hand Stow gang	1	5.0	5.0
Package Conveyor Ops.			
Package Conveyors	2	12.2	12.2
Fork lifts 01 DK	2	109.0	
Hand Stow gang	2	12.2	
		TOTAL M.T./HOUR	17.2

TOTAL ELAPSED TIME:

$$\frac{1000 \text{ M.T.}}{17.2} \div 8 = 7.29 \text{ SHIFTS}$$

APPENDIX A

ALTERNATIVE A LOADING TIME AND COSTS
(EXISTING SYSTEM 100% HAND STOW)

PERSONNEL AND EQUIPMENT COST

	Sub-group	Cost per Shift	X Number of Shifts
HAND STOW			(7.29)
Supervision	A (1)	$ 445.52	$ 3,247.84
Crane Crew	B (1)	474.24	3,457.21
Crane Crew (Ship's)	G (1)	234.24	1,707.61
Hand Stow Crews	C (3)	3,557.28	25,932.57
		TOTAL COST	$34,345.23

AVERAGE COST PER MEASUREMENT TON $34.345

THREE LOADS PER YEAR $ 103,036.

APPENDIX A

ALTERNATIVE B LOADING TIME AND COSTS
(PALLET CONVEYOR AND PALLET ELEVATOR)

LOADING

	Equip. Qty.	Stow Cap. M.T./Hour	Constrained Stow Capacity
A. PALLET STOW			
Fork lifts on Pier	4	150	
Mobile Crane Pier	2	114.8	114.8
Cargo Elev Frame 174			
Fork lift 01 DK	1	54.5	
Elevator	1	45.8*	
Palletized Stow w/fork lift	1	69.8	
Pallet Conv. Fr. 196			
Fork lift 01 DK	2	109	
Conveyor	1	69.8*	
Palletized Stow w/fork lift	1	69.8	
TOTAL PALLETIZED M.T./HOUR			114.8

* sum of elevator and conveyor capacity exceeds capacity of two cranes.

B. HAND STOW			
Fork lifts on Pier	1	37.5	
Mobile Crane Pier	1	57.4	
Fork lift 01 DK	1	54.5	
Cargo Elev Frame 174			
Elevator	1	38.7	
Hand Stow gang w/fork lift	1	13.6	13.6
Pallet Conv. Fr. 196			
Conveyor	1	43.6	
Hand Stow gang w/fork lift	1	13.6	13.6
TOTAL HAND STOW M.T./HOUR			27.2

TOTAL ELAPSED TIME:

Palletized Cargo $\frac{700 \text{ M.T.}}{114.8} \div 8 = .76$ SHIFTS

Hand Stow Cargo $\frac{300 \text{ M.T.}}{27.2} \div 8 = 1.38$ SHIFTS

TOTAL TIME 2.14 SHIFTS

APPENDIX B

ALTERNATIVE B LOADING TIME AND COSTS
(PALLET CONVEYOR AND PALLET ELEVATOR)

PERSONNEL AND EQUIPMENT COST

	Sub-group	Cost per Shift	X Number of Shifts
PALLET STOW			(.76)
Supervision	A (1)	$ 445.52	$ 338.59
Crane Crew	B (2)	948.48	720.84
Extra Fork lift Op.	I (2)	258.24	196.26
Pallet Stow gangs	D (2)	1,488.32	1,131.12
Extra F.L. op 01 DK	H (1)	93.12	70.77
	TOTAL COST FOR PALLET STOW		2,457.58
HAND STOW			(1.38)
Supervision	A (1)	$ 445.52	$ 614.82
Crane Crew	B (1)	474.24	654.45
Hand Stow gangs	C (2)	2,371.52	3,272.70
Fork lift Oper.	H (2)	186.24	257.01
	TOTAL COST FOR HAND STOW		4,798.98
TOTAL LOADING COST			$ 7,256.56
	AVERAGE COST PER M.T. =		$ 7.257
	THREE LOADS PER YEAR =		$21,770.

APPENDIX B

ALTERNATIVE C LOADING TIME AND COSTS
(TWO PALLET CONVEYORS)

LOADING

	Equip. Qty.	Stow Cap. M.T./Hour	Constrained Stow Capacity
A. PALLET STOW			
Fork lifts on Pier	4	150.	
Mobile Crane Pier	2	114.8	114.8
Pallet Conv. Fr 174 and Fr 196.			
Fork lifts 01 DK	3	163.5	
Pallet Conv.	2	139.6	
Palletized Stow w/fork lift	2	139.6	
TOTAL PALLETIZED M.T./HOUR			114.8
B. HAND STOW			
Fork lifts on Pier	2	75.0	
Mobile Crane Pier	1	57.4	
Pallet Conv. Fr 174 and Fr 196.			
Fork lifts 01 DK	1	54.5	
Pallet Conv.	2	139.6	
Hand Stow gang w/fork lift	2	27.2	27.2
TOTAL HAND STOW M.T./HOUR			27.2

TOTAL ELAPSED TIME:

Palletized Cargo $\frac{700 \text{ M.T.}}{114.8} \div 8 = .76$ SHIFTS

Hand Stow Cargo $\frac{300 \text{ M.T.}}{27.2} \div 8 = 1.38$ SHIFTS

TOTAL TIME 2.14 SHIFTS

APPENDIX C

ALTERNATIVE C LOADING TIME AND COSTS
(TWO PALLET CONVEYORS)

PERSONNEL AND EQUIPMENT COST

	Sub-Group	Cost per Shift	X Number of Shifts
PALLET STOW			(.76)
Supervision	A (1)	$ 445.52	$ 338.59
Crane Crew	B (2)	948.48	720.84
Extra F.L. Op Pier	I (2)	258.24	196.26
Pallet Stow gangs	D (2)	1,488.32	1,131.12
Extra F.L. Op. 01 DK	H (1)	93.12	70.77
	TOTAL COST FOR PALLET STOW		2,457.58
HAND STOW			(1.38)
Supervision	A (1)	$ 445.52	$ 614.82
Crane Crew	B (1)	474.24	654.45
Hand Stow gangs	C (2)	2,371.52	3,272.70
Fork lift Oper.	H (2)	186.24	257.01
	TOTAL COST FOR HAND STOW		4,798.98
TOTAL LOADING COST			$ 7,256.56
	AVERAGE COST PER M.T. =		$ 7.257
	THREE LOADS PER YEAR =		$ 21,770.

APPENDIX C

ALTERNATIVE D LOADING TIME AND COSTS
(YARD AND STAY SYSTEM)

LOADING

	Equip. Qty.	Stow Cap. M.T./Hour	Constrained Stow Capacity
A. PALLET STOW			
Fork lifts on Pier	1	37.5	
Yard and Stay	1	22.2	22.2
Palletized Stow w/fork lift	1	69.8	
TOTAL PALLETIZED M.T./HOUR			22.2
B. HAND STOW			
Fork lifts on Pier	1	37.5	
Yard and Stay	1	22.2	
Hand Stow gang w/fork lift	1	13.6	13.6
TOTAL HAND STOW M.T./HOUR			13.6

TOTAL ELAPSED TIME:

Palletized Cargo $\frac{700\text{ M.T.}}{22.2} \div 8 = 3.94$ SHIFTS

Hand Stow Cargo $\frac{300\text{ M.T.}}{13.6} \div 8 = 2.76$ SHIFTS

TOTAL TIME 6.7 SHIFTS

APPENDIX D

ALTERNATIVE D LOADING TIME AND COSTS
(YARD AND STAY SYSTEM)

PERSONNEL AND EQUIPMENT COST

	Sub-group	Cost per Shift	X Number of Shifts
PALLET STOW			(3.94)
Supervision (less pier foreman)	A (1)	$ 284.08	$ 1,119.28
Pallet Stow gang	F (1)	885.28	3,488.00
TOTAL COST FOR PALLET STOW			4,607.28
HAND STOW			(2.76)
Supervision (less pier foreman)	A (1)	$ 284.08	$ 784.06
Hand Stow gang	E (1)	1,063.52	2,935.32
TOTAL COST FOR HAND STOW			3,719.38
TOTAL LOADING COST			$ 8,326.66
AVERAGE COST PER M.T.		=	$ 8.327
THREE LOADS PER YEAR		=	$24,980.

APPENDIX D

ALTERNATIVE E LOADING TIME AND COSTS
(SHIPBOARD CRANE)

LOADING

	Equip. Qty	Stow Cap. M.T./Hour	Constrained Stow Capacity
A. PALLET STOW			
Fork lifts on Pier	1	37.5	
Shipboard Crane	1	24.0	24.0
Palletized Stow w/fork lift	1	69.8	
TOTAL PALLETIZED M.T./HOUR			24.0
B. HAND STOW			
Fork lifts on Pier	1	37.5	
Shipboard Crane	1	24.0	
Hand Stow gang w/fork lift	1	13.6	13.6
TOTAL HAND STOW M.T./HOUR			13.6

TOTAL ELAPSED TIME:

Palletized Cargo $\frac{700 \text{ M.T.}}{24.0} \div 8 = 3.64$ SHIFTS

Hand Stow Cargo $\frac{300 \text{ M.T.}}{13.6} \div 8 = 2.76$ SHIFTS

TOTAL TIME 6.4 SHIFTS

APPENDIX E

ALTERNATIVE E LOADING TIME AND COSTS
(SHIPBOARD CRANE)

PERSONNEL AND EQUIPMENT COST

	Sub-group	Cost per Shift	X Number of Shifts
PALLET STOW			(3.64)
Supervision (less pier foreman)	A (1)	$ 284.08	$ 1,034.05
Pallet Stow gang	F (1)	885.28	3,222.42
	TOTAL COST FOR PALLET STOW		4,256.47
HAND STOW			(2.76)
Supervision (less pier foreman)	A (1)	$ 284.08	$ 784.06
Hand Stow gangs	E (1)	1,063.52	2,935.32
	TOTAL COST FOR HAND STOW		3,719.38
TOTAL LOADING COST			$ 7,975.84

AVERAGE COST PER M.T. = $ 7.976

THREE LOADS PER YEAR = $23,928.

APPENDIX E

ALTERNATIVE F LOADING TIME AND COSTS
(SIDE LOADING TRANSPORTER)

LOADING

	Equip. Qty.	Stow Cap. M.T./Hour	Constrained Stow Capacity
A. PALLET STOW			
Fork lifts on Pier	1	37.5	
Side Loading Transporter	1	19.4	19.4
Palletized Stow w/fork lift	1	48.0	
TOTAL PALLETIZED M.T./HOUR			19.4
B. HAND STOW			
Fork lifts on Pier	1	37.5	
Side Loading Transporter	1	19.4	
Hand Stow gang w/fork lift	1	13.6	13.6
TOTAL HAND STOW M.T./HOUR			13.6

TOTAL ELAPSED TIME:

Palletized Cargo $\frac{700 \text{ M.T.}}{19.4} \div 8 = 4.51$ SHIFTS

Hand Stow Cargo $\frac{300 \text{ M.T.}}{13.6} \div 8 = 2.76$ SHIFTS

TOTAL TIME 7.27 SHIFTS

APPENDIX F

ALTERNATIVE F LOADING TIME AND COSTS
(SIDE LOADING TRANSPORTER)

PERSONNEL AND EQUIPMENT COST

	Sub-group	Cost per Shift	X Number of Shifts
PALLET STOW			(4.51)
Supervision (less pier foreman)	A (1)	$ 284.08	$ 1,281.20
Pallet Stow gangs	F (1)	885.28	3,992.61
TOTAL COST FOR PALLET STOW			5,273.81
HAND STOW			(2.76)
Supervision (less pier foreman)	A (1)	$ 284.08	$ 784.06
Hand Stow gang	E (1)	1,063.52	2,935.32
TOTAL COST FOR HAND STOW			3,719.38
TOTAL LOADING COST			$ 8,993.19

AVERAGE COST PER M.T. = $ 8.993

THREE LOADS PER YEAR = $26,980.

APPENDIX F

PROJECTED AND DISCOUNTED COST SAVINGS FOR
ALTERNATIVES B AND C

YEAR	INFLATION[27] FACTOR 6%	DISCOUNT[28] FACTOR 10%	ANNUAL SAVINGS $81,266	CRANES RENT (1) AVOIDANCE $1,541
1	1.0	.954	$77,528	$1,470
2	1.06	.867	74,685	1,416
3	1.124	.788	71,978	1,365
4	1.191	.717	69,397	1,316
5	1.262	.652	66,868	1,268
6	1.338	.592	64,370	1,221
7	1.418	.538	61,996	1,176
8	1.504	.489	59,768	1,133
9	1.594	.445	57,644	1,093
10	1.689	.405	55,590	1,054
11	1.791	.368	53,561	1,016
12	1.898	.334	51,517	977
13	2.012	.304	49,706	943
14	2.133	.276	47,842	907
15	2.261	.251	46,119	874
PRESENT VALUE OF ANNUAL SAVINGS-			$908,569	$17,229

NOTES:
(1) 2.14 shifts X 8 hours/shift X 3 loadings/year X $30./Hr rental = $1,541.

---

[27] Department of the Air Force, Economic Analysis Handbook, 18 October 1972, p. 16.

[28] Federal Reserve Bank of St. Louis, National Economic Trends, March 1974. Present consumer price index inflation rate is 9-10% annually, but has been at 5% for the past 5 years and is expected to level out at 5% to 7% by the end of 1974. Therefore, the author picked 6% as a conservative long run inflation rate for heavy equipment rentals.

APPENDIX G

APPENDIX H

HOURLY RATES FOR STEVEDORES, "EXTRA LABOR CATEGORY" and STEVEDORE AND EQUIPMENT COSTS

This appendix provides current and historical stevedore "extra labor" wage rates negotiated by the Pacific Maritime Administration and the International Longshoremen's and Warehousemen's Union, which are applicable to the loading of the AOE ships, in the port of Seattle, Washington. For ease in computation of stevedore personnel costs in the model, the average wage per shift for each position is computed. This computation includes automatic overtime where applicable.

The required manpower assignments for current operations (alternative A) are broken into subgroups of supervision, crane crew, hand stowage and pallet stowage for ease in computing shift charges based on average hourly wages. This provides a dollar value per shift for each subgroup including contractor fork lift and crane rental.

Stevedore costs for proposed systems such as yard and stay, crane and side loading transporter, are estimated by developing hypothetical subgroups. These are priced out in the same manner and at the same wage rates as the subgroups identified for current operations. Extra stevedores and equipment are necessary to support the additional crane and fork lift requirements of alternatives B and C. These extra men and equipment are also priced out on an average cost eight hour shift basis.

"Extra Labor" category rates are used for AOE loading in Seattle vice commodity rates, because contractors will not bid on the AOEs on a commodity basis as is normally done with commercial cargo. The reason for this is the ship's design, which prevents rapid loading, and the relatively small total load (500 to 1000 measurement ton).

The "rules" column indicates the standard and overtime hours applied by union rules to the regular eight hour shift. Union rules call for a given number of hours paid at regular pay plus an automatic overtime differential based on skill. The first figure under the rules column is the number of hours per day charged at regular time rates. The second figure is the additional overtime differential charged on the basis of skill. For instance the supercargo receives 8 hours at regular time plus 2 hours calculated at overtime for a normal eight hour day time shift. If the rule is 6 + 3, then the average hourly charge is equal to

$$\frac{(\text{Std rate X 6}) + (\text{Std rate X 3 X 1.5})}{8} .$$

For subgroup calculations, quantities of personnel are patterned after historical assignments made at Pier 91 in Seattle for loading ACE 1 and 2. Foremen are assigned to each gang because of historic equipment malfunctions and numerous line items requiring close control within each space. These teams for hand stowage and pallet stowage can't be equated to "standard" stevedore gangs assigned to

load conventional cargo ships which are bid on a commodity rate basis. Because of the AOE's materials handling restrictions in handling provisions, the supervisor must have maximum flexibility to move his gangs from space to space. The numbers of foremen are considered necessary to maintain this flexibility and retain control of the numerous line items being loaded so as to comply with the ship's loading plan. Shifting gangs from compartment to compartment in the hold of the ship requires timely action by the foreman on the pier to ensure that the right cargo has commenced loading for the new compartment assignment.

To compute the average hourly cost for each subgroup, in the following detailed "stevedore personnel and equipment assignments and costs," the average hourly rate for each position from column 8 on page 126 is multiplied by the quantity listed in the second column.

The figures in parenthesis in the second column indicate the number of additional Navy fork lifts aboard the AOE used in the loading operation. These fork lifts are also driven by contractor personnel, but the Navy is charged only for the labor of the fork lift drivers operating the Navy fork lifts on the ship. However, the fork lifts on the pier belong to the contractor, and the Navy is charged $4.50 per hour per fork lift plus the fork lift driver's labor rate for this equipment.

Cost computations in this section reflect minimum costs. Actual loading is frequently subject to overtime shifts, delays because of equipment malfunction on the ship, "penalty" cargo and other charges which accelerate many of these rates.

The letters in parenthesis are used to identify the per shift cost of labor and rented equipment requirements associated with different subgroups or components of each system. The sum of the labor and equipment costs for a system is the sum of the total average costs per shift of the several components.

HOURLY RATES "EXTRA LABOR" CATEGORY: REGULAR TIME (O.T. = 1.5 X Std. Time)

POSITION	1 RULES	2 1966	3 1969	4 1970	5 1972	6 1973	7 1974	8 1973/1974 AVR/HR.
Super Cargo	8 + 2	8.165	10.135	10.62	11.635	13.58	13.58	18.67
Foreman	6 + 4	7.975	9.90	10.37	11.585	13.455	13.455	20.18
Supervisor	8 + 2	7.29	9.09	9.53	10.465	12.25	12.25	16.84
Clerk	8 + 0	6.625	8.26	8.665	9.52	11.14	11.14	11.14
Crane Operator	6 + 3	6.50	8.065	8.425	9.72	11.16	11.16	14.64
Fork Lift Operator	6 + 2	6.28	7.795	8.155	8.91	10.35	10.35	11.64
Stevedore	6 + 2	5.95	7.345	7.705	8.46	9.90	9.90	11.14

APPENDIX H

STEVEDORE PERSONNEL AND EQUIPMENT CONSTS: by subgroup

	Qty.		Qty. X Avr. Cost/Hour	Total Avr. Cost/ Hour X 8 Hr. Shift	
Supervision					
Super Cargo	1		$ 18.67		
Supervisor	1		16.84		
Foreman (Pier)	1		20.18		
TOTAL			55.69	$ 445.52	(A)
1. STOWAGE WITH CONVEYORS AND ELEVATORS.					
Crane and Crew					
Crane Mobile (hire)	1		30.00		
Crane Operators	2		29.28		
			59.28	$ 474.24	(B)
Hand Stowage					
Foreman	1		20.18		
Clerk	1		11.14		
Fork lifts	1	(1)	4.50		
Fork lift Oper.	2		23.28		
Stevedores	8		89.12		
			148.22	$ 1,185.76	(C)
Pallet Stowage					
Foreman	1		20.18		
Clerk	1		11.14		
Fork lifts	1	(2)	4.50		
Fork lift Oper.	3		34.92		
Stevedores	2		22.28		
			93.02	$ 744.16	(D)
2. STOWAGE WITH YARD AND STAY, SIDE LOADER OR CRANE WITH AMIDSHIP HATCHES.					
Hand Stowage					
Foreman	1		20.18		
Clerk	1		11.14		
Crane (winch) Op.	2		29.28		
Fork lifts	1	(1)	4.50		
Fork lift Oper.	2		23.28		
Stevedores	4		44.56		
			132.94	$ 1,063.52	(E)

APPENDIX H

	Qty.	Qty. X Avr. Cost/Hour	Total Avr. Cost/ Hour X 8 Hr. Shift
Pallet Stowage			
Foreman	1	$ 20.18	
Clerk	1	11.14	
Crane (winch) Op.	2	29.28	
Fork lifts	1 (1)	4.50	
Fork lift Oper.	2	23.28	
Stevedores	2	22.28	
		110.66	$ 885.28 (F)

3. EXTRA OPERATORS AND EQUIPMENT

Crane operators	2	29.28	$ 234.24 (G)
Fork lift Oper.	1	11.64	$ 93.12 (H)
Fork lift and	1	4.50	
operator	1	11.64	
		16.14	$ 129.12 (I)

APPENDIX H

APPENDIX I

CARGO HANDLING EVOLUTIONS AND CAPACITIES

The cargo movement capacities of the individual pieces of equipment in each of the alternative systems is computed in this appendix. The hypothetical capacities, or actual capacities in the case of existing systems, of stevedore gangs to stow cargo is also computed. For consistency in measurement, the following standards are applied:[29,30]

1. DISTANCES Actually measured by the author while onboard the ship and Pier 91 facilities in Seattle, or measured from blueprints and drawings of AOE 1 provided by NSY Puget Sound.

2. FORK LIFT SPEED 5mph or 440 feet per minute.

3. FORK LIFT LOAD/UNLOAD TIME .3 minutes

4. STANDARD DELAY FACTOR FOR MATERIALS MOVEMENT EVOLUTION 25%

5. ACCELERATION/DECELERATION FACTOR FOR HOISTS, ELEVATORS, CRANES, ETC. .05 minutes

6. HOIST AND SWING SPEED FOR CRANES 300 feet per minute and 3.0 r.p.m. respectively. These are average speeds computed from technical data provided by four different manufacturers.

7. Speeds for conveyors, elevators, and other equipment presently onboard was recorded from technical data available on the specific equipment.

---

[29] Department of the Navy, Storage and Materials Handling, NAVSUP PUB 284, 31 July 1963, Change 26, p. 44-5.

[30] Staniar, William, Plant Engineering Handbook, McGraw Hill Book Company, New York 1959, p. 28-78.

8. Rates of stowage and other time factors not identified above were developed from historical loading data for the AOEs, or by actual stopwatch measurement during the January 1974 loading of the USS Sacramento.

CARGO HANDLING EVOLUTIONS AND CAPACITIES

EVOLUTION	Distance	Speed fpm/rpm	Time (minutes)
PALLET STOW			
From pallet conveyor, elevator, etc. and stacking in palletized mode.			
(1) Single pallet/tray			
Move fwd & pickup load	4 ft	440 fpm	.3
Back & turn	10	440	.02
Forward	14	440	.03
Position & release ld.			.3
Back up	14	440	.03
Return for next load	6	440	.01
			.69
Add: 25% standard delay			.17
			.86

CAPACITY = 69.8 M.T./HOUR

EVOLUTION	Distance	Speed fpm/rpm	Time (minutes)	
(2) Two Pallets/tray (elevator & side loader only)				
Move fwd & pickup load	4 ft	440 fpm	.3	
Back up	8	440	.02	
Fwd position & release load #1	4		.3	
Back up	4	440	.01	
Fwd & pickup load #2	8	440	.31	
Back & turn	10	440	.02	
-subtotal, elevator empty				.96
Forward	14	440	.03	
Position & release ld #2			.3	
Back up	14	440	.03	
Fwd & pickup load #1	4	440	.3	
Back up	4	440	.01	
Forward	14	440	.03	
Position & release ld #1			.3	
Back up	14	440	.03	
Return for next cycle	6	440	.01	
			2.00	
Add: 25% standard delay			.5	
			2.5	

CAPACITY = 48.0 M.T./HOUR

APPENDIX I

EVOLUTION	Distance ft/deg.	Speed fpm/rpm	Time (minutes)

HAND STOW

From package conveyors and shipboard crane through small hatch system (present method). Without fork lift in storeroom.

(1) Package Conveyor:
see section on conveyance equipment for equipment capacity. Hand stowage is constrained by equipment capacity.

CAPACITY = 6.1 M.T./HOUR

(2) Shipboard Crane:
see section on conveyance equipment for equipment capacity. For hand stow in storeroom without fork lift, from palletized loads in the square hatch, the capacity of hand stow gang is 5 M.T./Hour based on historical data of AOE 1.

CAPACITY = 5.0 M.T./HOUR

From pallet conveyor, elevator or amidship hatch system, etc. With a fork lift in the storeroom

(3) Single pallets only.

Move fwd & pickup load	4 ft	440 fpm	.3
Back up & turn	10	440	.02
Forward	14	440	.03
Position & release ld			.3
-fork lift operational subtotal			.65
Hand stow 40 cases			3.0
			3.65
Add: 25% standard delay on hand stow			.75
			4.40

CAPACITY = 13.6 M.T./HOUR

APPENDIX I

EVOLUTION	Distance ft/deg.	Speed fpm/rpm	Time (minutes)
HOIST EQUIPMENT (DIRECT PIER TO HOLD)			
(1) Yard and Stay System			
Load robot (1 pallet)			.3
Lift to clear 02 DK	52 ft	300 fpm	.17
acceleration factor			.05
Swing horizontal	90	300	.3
Lower to 4th DK	64	300	.21
deceleration factor			.05
Unload pallet			.3
Lift robot clear 02 DK	64	300	.21
acceleration factor			.05
Swing horizontal, to pier	90	300	.3
Lower to pier	52	300	.17
deceleration factor			.05
			2.16
Add: 25% standard delay			.54
			2.70

CAPACITY = 22.2 M.T./HOUR

EVOLUTION	Distance ft/deg.	Speed fpm/rpm	Time (minutes)
(2) Crane with Hatch amidship			
Load robot (1 pallet)			.3
Lift to clear 02 DK	52 ft	300 fpm	.17
acceleration factor			.05
Swing to amidship	120 deg.	3.rpm	.11
deceleration factor			.05
Position over hatch			.17
Lower to 4th DK	64 ft	300 fpm	.21
deceleration factor			.05
Unload pallet			.3
Lift robot clear 02 DK	64	300 fpm	.21
acceleration factor			.05
Swing to pier	120 deg.	3.rpm	.11
Lower to pier	52 ft	300 fpm	.17
deceleration factor			.05
			2.0
Add: 25% standard delay			.5
			2.5

CAPACITY = 24 M.T./HOUR

APPENDIX I

EVOLUTION	Distance ft/deg.	Speed fpm/rpm	Time (minutes)

HOIST EQUIPMENT (DIRECT PIER TO HOLD (Cont'd)

(3) Side Loading Transporter			
Load Platform (2 pallets)			.5
Lift carriage to track	32 ft	89 fpm	.4
accel/deceleration			.05
Horizontal travel	80	125 fpm	.64
accel/deceleration			.05
Lower to 4th DK	44	80 fpm	.55
deceleration			.05
Unload 2 pallets (1 f.l.) (see pallet stow (2))			.96
Lift carriage to track	44	80	.55
accel/deceleration			.05
Horizontal travel to pier	80	125	.64
accel/deceleration			.05
Lower to pier	32	80	.4
deceleration			.05
			4.94
	Add: 25% standard delay		1.24
			6.18

CAPACITY = 19.4 M.T./HOUR

HOIST EQUIPMENT (PIER TO 01 DECK)

(4) Mobile Crane on pier			
Load robot (2 pallets)			.5
Lift robot clear of 01 DK	36 ft	300 fpm	.12
accel/deceleration			.05
Swing to 01 DK	60 deg	3 rpm	.06
accel/deceleration			.05
Lower to 01 DK	8 ft	300 fpm	.03
deceleration			.05
Unload 2 pallets (2 f.l.)			.5
Lift robot clear 01 DK	8	300	.03
acceleration			.05
Swing	60 deg	3 rpm	.06
Lower to pier	36 ft	300 fpm	.12
deceleration			.05
			1.67
	Add: 25% standard delay		.42
			2.09

CAPACITY = 57.4 M.T./HOUR

APPENDIX I

EVOLUTION	Distance ft/deg.	Speed fpm/rpm	Time (minutes)

CONVEYANCE EQUIPMENT (01 DECK TO HOLD)

(1) Package Conveyors			
Fork lift removes empty pallet and positions loaded pallet in front of conveyor on 01 DK from Crane			1.0
Start Conveyor and wait for first shelf			.11
Feed 40 boxes into conveyor at 6 packages per minute			6.7
			7.81
Add: 25% standard delay			1.95
			9.76

CAPACITY = 6.1 M.T./HOUR
FOR TWO PACKAGE CONVEYORS
CAPACITY = 12.2 M.T./HOUR

(2) Pallet Elevator (single pallet per load)			
Fork lift places load on elevator.			.3
Lower to 4th DK	40 ft	150 fpm	.27
accel/deceleration			.05
Unload pallet in Strm.			.3
Lift elevator to 01 DK	40 ft	150	.27
accel/deceleration			.05
			1.24
Add: 25% standard delay			.31
			1.55

CAPACITY = 38.7 M.T./HOUR

Note: at 60 fpm (present speed on AOE 4) Cap. = 23.6 M.T.

(3) Pallet Elevator (two pallets per load with two fork lifts on the 01 DK)			
Fork lifts place two pallets on elevator			.5
Lower Elevator to 4th DK	40 ft	150 fpm	.27
accel/deceleration			.05
Unload 2 pallets (1 f.l.)			.96
Lift elevator to 01 DK	40 ft	150	.27
accel/deceleration			.05
			2.10
Add: 25% standard delay			.52
			2.62

CAPACITY = 45.8 M.T./HOUR

APPENDIX I

EVOLUTION	Distance ft/deg.	Speed fpm/rpm	Time (minutes)
CONVEYANCE EQUIPMENT (01 DECK to HOLD Cont'd)			
(4) Pallet Elevator (two pallets per load with one fork lift on the 01 DKO			
Fork lift places first pallet on elevator			.3
Fork lift places second pallet on elev. see section on fork lifts 01 DK.			1.1
Lower elevator	40 ft	150 fpm	.27
accel/deceleration			.05
Unload 2 pallets (1 f.l.)			.96
Lift elevator to 01 DK	40 ft	150 fpm	.27
accel/deceleration			.05
			3.00
Add: 25% standard delay			.75
			3.75

CAPACITY = 31.9 M.T./HOUR

Note: Capacity at present 60 fpm elevator speed would be 25.3 M.T./Hour with one fork lift on 01 DK, and 33.2 M.T./Hour with two fork lifts on 01 DK.

EVOLUTION	Distance ft/deg.	Speed fpm/rpm	Time (minutes)
(5) Pallet Conveyor (one fork lift on 01 DK)			
Fork lift places pallet on tray			.3
Lower Conv. to 3rd tray	20 ft	30 fpm	.67
accel/deceleration			.05
(Subtotal .67 + .05 lowering Conv and stop)			.72
Fork lift places second pallet on tray. (see fork lift section) (1.1 - .72)			.38
Lower Conv. to 5th tray	20 ft	30 fpm	.67
accel/deceleration			.05
Unload first tray in hold and load 5th tray on 01 DK (1.1 - .72)			.38
Time to get first load to storeroom			2.5

Repetitive load cycle is then .67 + .05 + .38 + 25% or 1.375 minutes.

CAPACITY = 43.6 M.T./HOUR

Note: Capacity is constrained by one fork lift on 01 deck, and shelf spacing and rotation speed of the conveyor.

APPENDIX I

EVOLUTION	Distance ft/deg.	Speed fpm/rpm	Time (minutes)
CONVEYANCE EQUIPMENT (01 DECK TO HOLD Cont'd)			
(6) Pallet Conveyor (two fork lifts on 01 DK)			
1st fork lift places pallet on 1st tray			.3
Lower Conv. to 2nd tray	10 ft	30 fpm	.33
accel/deceleration			.05
2nd f.l. places pallet on 2nd tray			.3
Lower Conv. to 3rd tray	10 ft	30 fpm	.33
accel/deceleration			.05
1st f.l. places pallet on 3rd tray			.3
Lower Conv. to 4th tray	10 ft	30 fpm	.33
accel/deceleration			.05
2nd f.l. places pallet on 4th tray			.3
Lower Conv. to 5th tray	10 ft	30 fpm	.33
accel/deceleration			.05
Unload 1st tray in hold, and load 5th tray on 01 DK			.3
Time to get first load to the storeroom			3.02

Repetitive load cycle is then .33 + .05 + .3 + 25% or .85 minutes on the 01 deck. However pallet stow with only one fork lift in the storeroom is .86 minutes which effectively constrains this equipment to .86 minutes, thus

CAPACITY = 69.8 M.T./HOUR

EVOLUTION	Distance ft/deg.	Speed fpm/rpm	Time (minutes)
(7) Ship's Crane lowering cargo through 7 ft X 9 ft hatch system.			
Fork lift position load on 01 DK			.2
Stevedore attach slings			.16
Lift clear of 02 DK	22 ft	100 fpm	.22
accel factor			.05
Swing load to hatch	90 deg	1.5 rpm	.17
deceleration			.05
Position load over hatch and adjust during decent			1.00
Lower to 4th DK	64 ft	100 fpm	.64
accel/deceleration			.05
Remove Slings			.10
Lift to clear 02 DK	64	100	.64
accel			.05
Swing to 01 DK port side	90 deg	1.5 rpm	.17
Lower to 01 DK	22 ft	100 fpm	.22
deceleration			.05
			3.77
Add: 25% standard delay			.94
			4.71

APPENDIX I

EVOLUTION	Distance ft/deg.	Speed fpm/rpm	Time (minutes)

CONVEYANCE EQUIPMENT (01 DECK TO HOLD Cont'd)

(7) continued
4.71 minutes is equivalent to a capacity of 12.7 M.T./Hr, however the pallets are accumulated in the square of the small hatch system and one lift out of each 4 is lost in retrograde movement of empty pallets. Out of each hour this involves the loss of 3 trips at 4.71 minutes plus the waiting time for 3 pallets to be unloaded in the square of the hatch so that pallet and the three empty pallets under it can be removed. This amounts to 23.13 minutes per hour. Therefore the effective productive time of this system is 60 - 23.13 or 36.87 minutes per hour. Divided by 4.71 minutes provides a productive

CAPACITY = 7.8 M.T./HOUR

EVOLUTION	Distance ft/deg.	Speed fpm/rpm	Time (minutes)
FORK LIFT EQUIPMENT			
(1) On 01 DK Moving cargo from wing of deck to elevator or conveyor amidship.			
Move forward & pickup load	4 ft	440 fpm	.3
Back up & turn	12 ft	440	.03
Move load to elev/conv	56 ft	440	.13
Position & release ld.			.3
Back up	12 ft	440	.03
Return & await next lift	40 ft	440	.09
			.88
Add: 25% standard delay			.22
			1.10

CAPACITY = 54.5 M.T./HOUR per FORK LIFT (X 2 = 109)

(2) On 01 DK moving cargo from starboard wing to port wing and place under the ship's crane at frame 183.			
Move fwd & pickup load	4 ft	440 fpm	.3
Back up & turn	12 ft	440	.03
Move to port side	102	440	.23
Position & release load			.3
Back up & turn	12	440	.03
Return to starbd. side	86	440	.20
			1.09
Add: 25% standard delay			.27
			1.36

CAPACITY = 44.1 M.T./HOUR per FORK LIFT (X 2 = 88.2)

(3) On the pier moving cargo to the robot or other hoisting equipment.			
Move fwd & pickup load	4 ft	440 fpm	.3
Back up & turn	4 ft	440	.01
Move load to hook	150 ft	440	.34
Position load on robot			.3
Back up	4	440	.01
Return to cargo shed	150 ft	440	.34
			1.3
Add: 25% standard delay			.3
			1.6

CAPACITY = 37.5 M.T./HOUR per FORK LIFT

Note: Usually one fork lift is assigned on the pier for each gang working in the hold, but this is not a rigid requirement.

APPENDIX I

"AOEs 1 AND 2 PROVISIONS CARGO SPACE HOLD NO. 5"

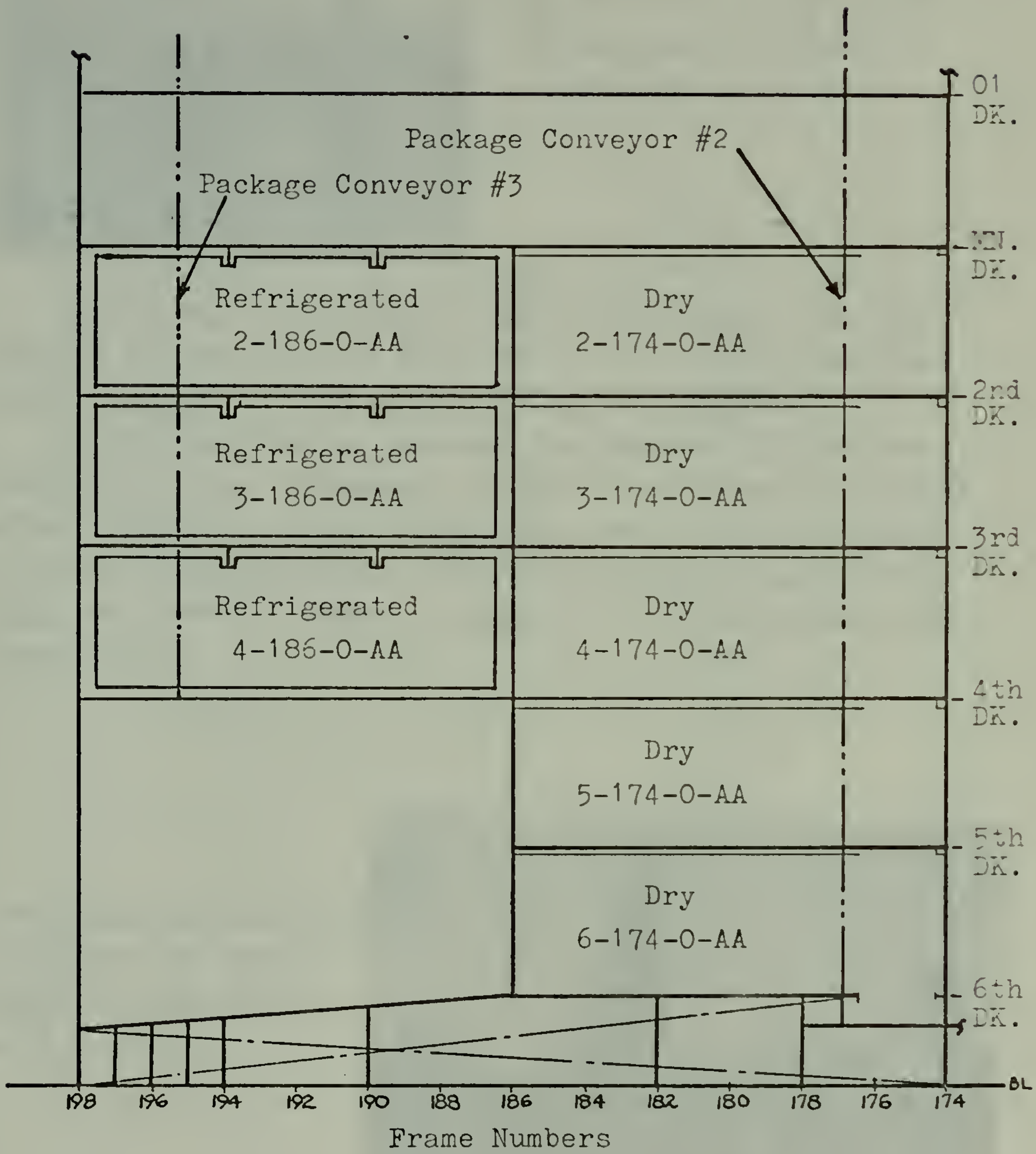
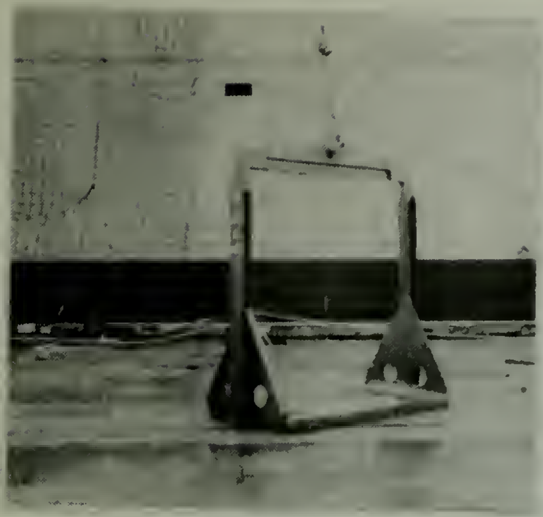


FIGURE 1



"ROBOT GEAR"

A rigid steel platform on which cargo can be placed for movement by crane or other lifting equipment.

Robots may be a "single" robot, as pictured here for lifting one pallet at a time, or a double robot (two feet longer) which is capable of lifting two pallets.

Robots may also be designed for peculiar lifting requirements. For instance, an open face "C" robot is very effective for handling bundles of plywood or other large rectangular cargo units. The "C" robot is designed with only one vertical member to support the platform from the cargo hook.

Provisions being loaded aboard USS SACRAMENTO 31 January 1974 with a robot.

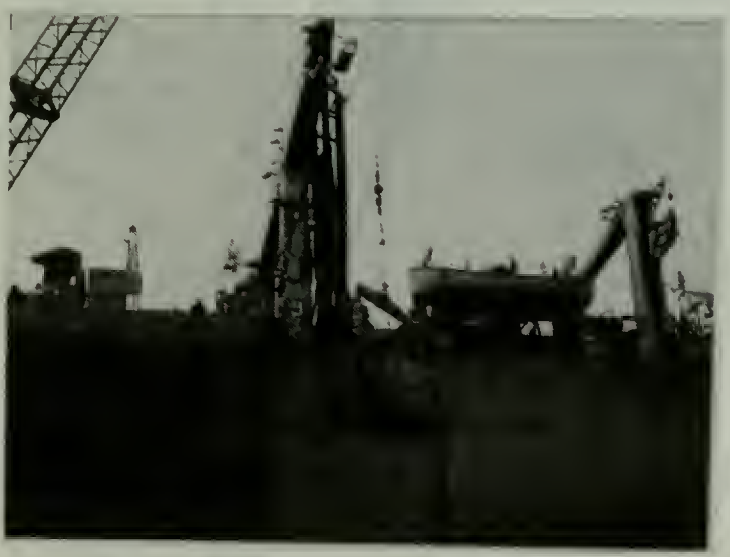
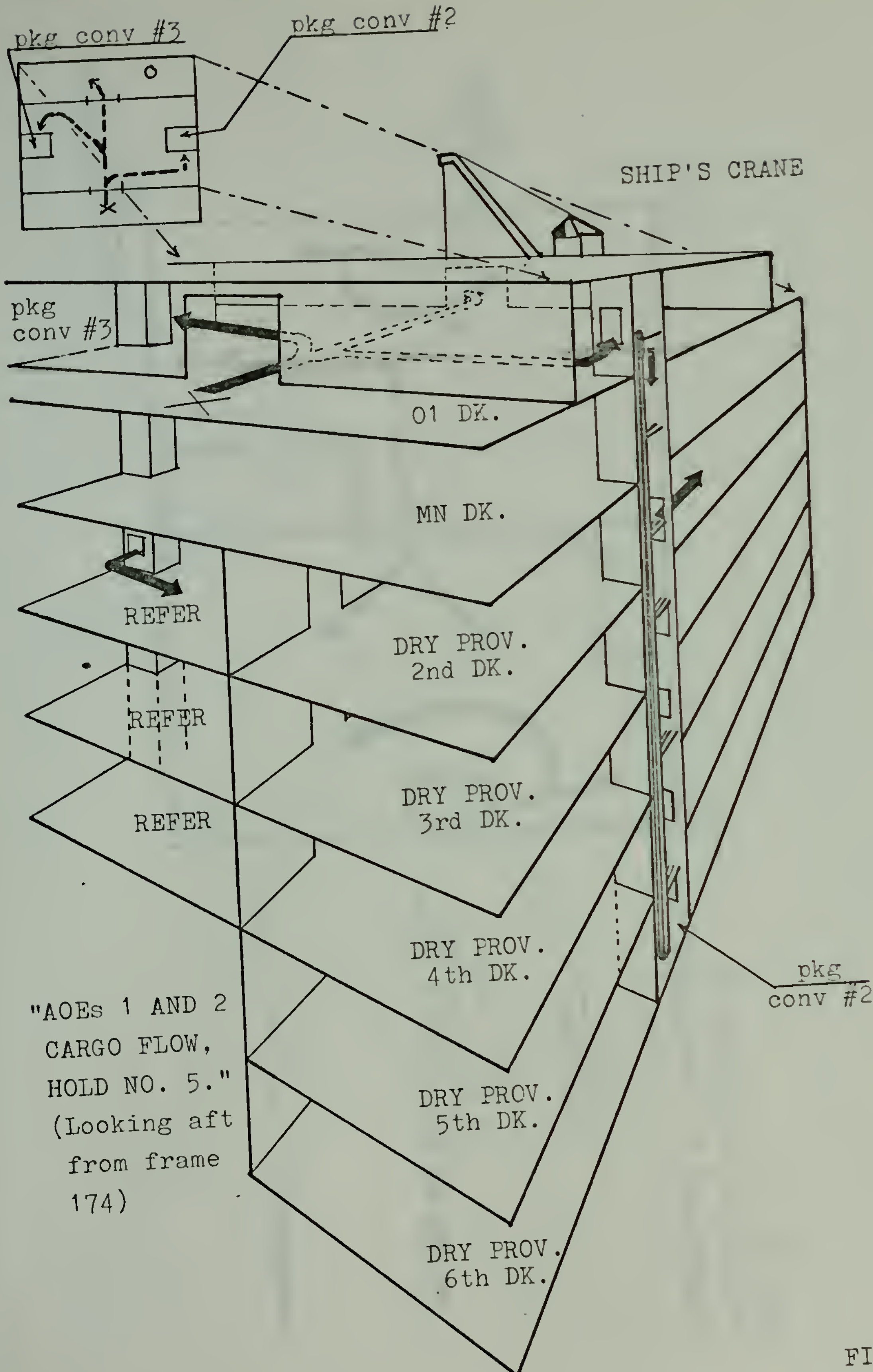
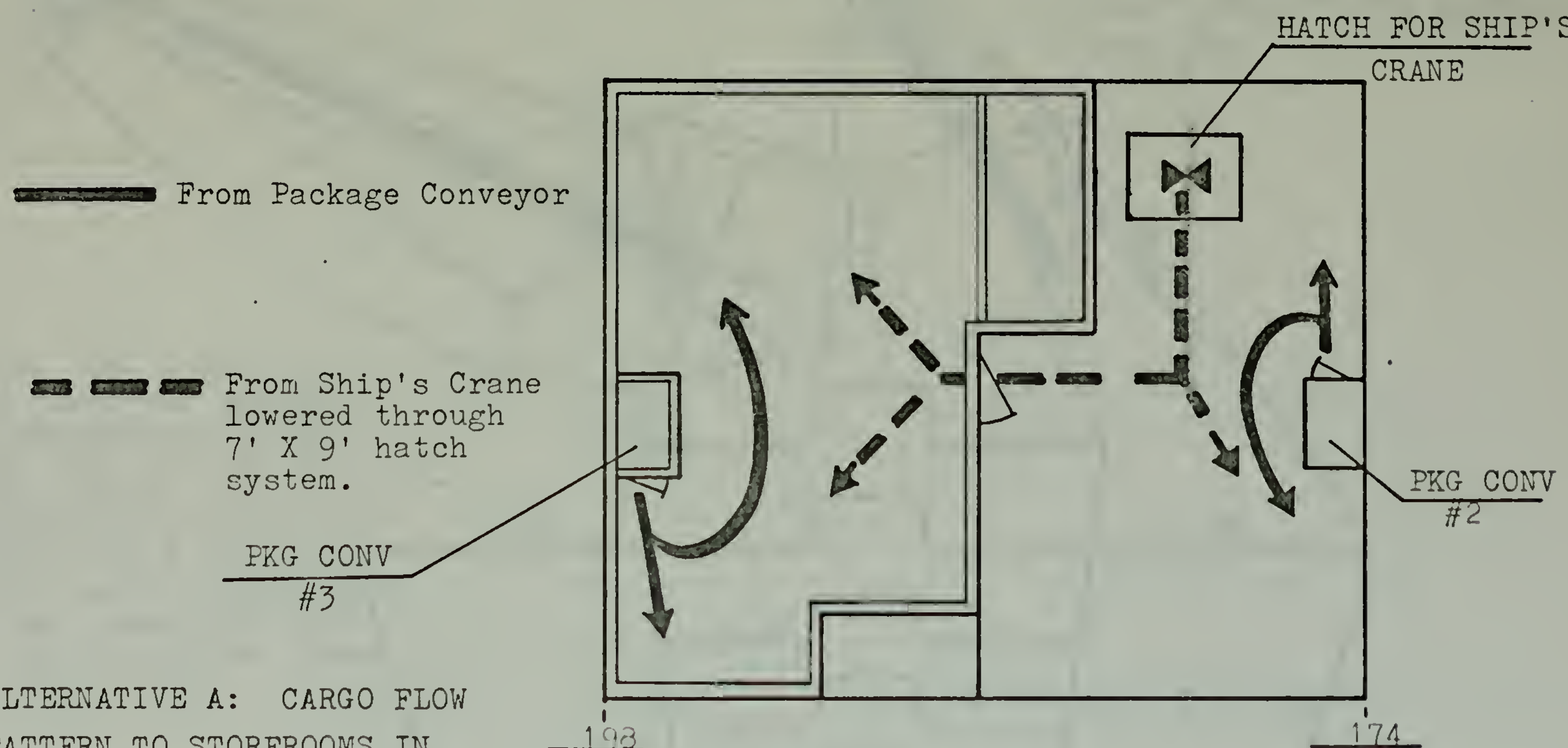


FIGURE 2



"AOEs 1 AND 2 CARGO FLOW, HOLD NO. 5." (Looking aft from frame 174)

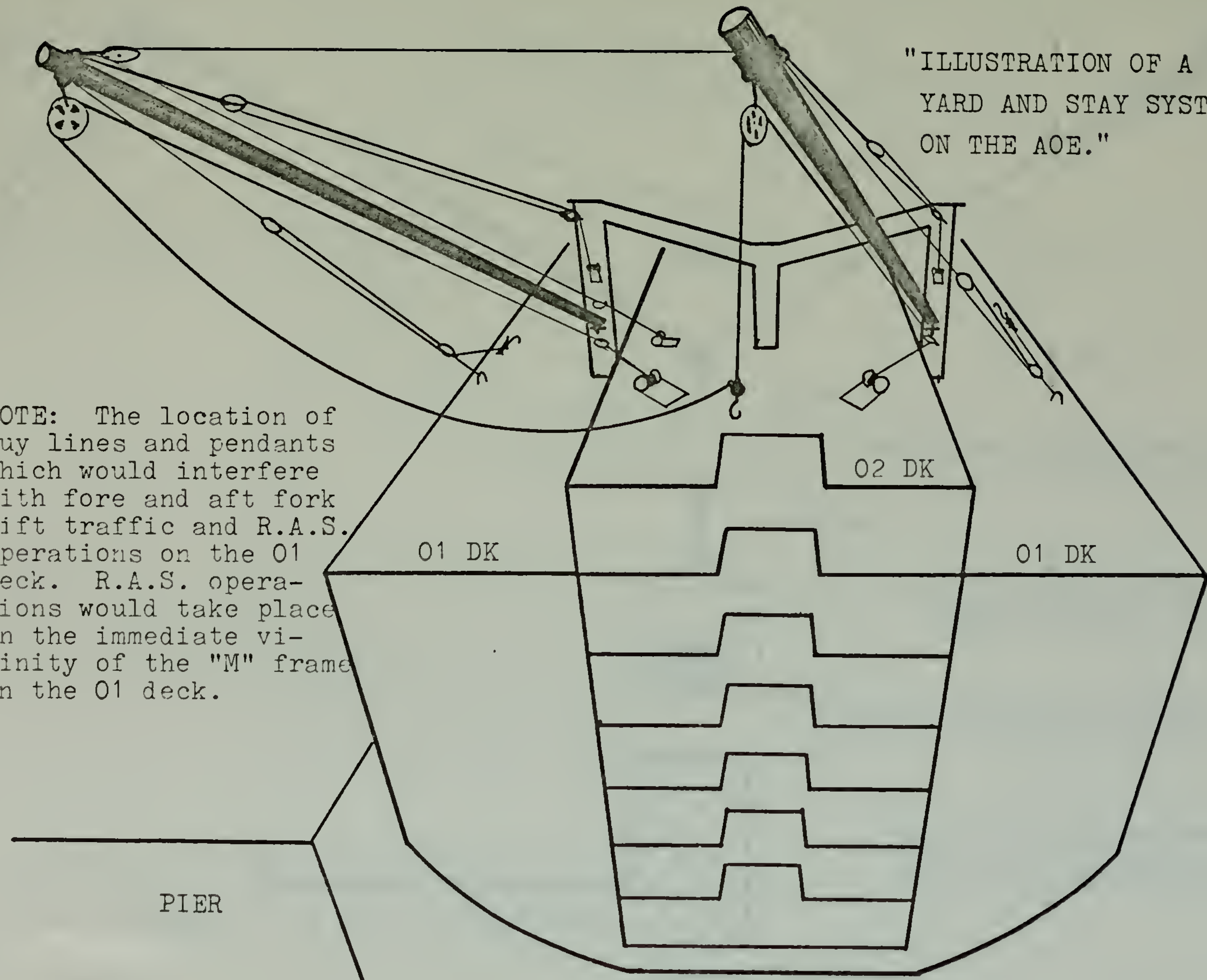
FIGURE 3



"ALTERNATIVE A: CARGO FLOW PATTERN TO STOREROOMS IN HOLD NO. 5."

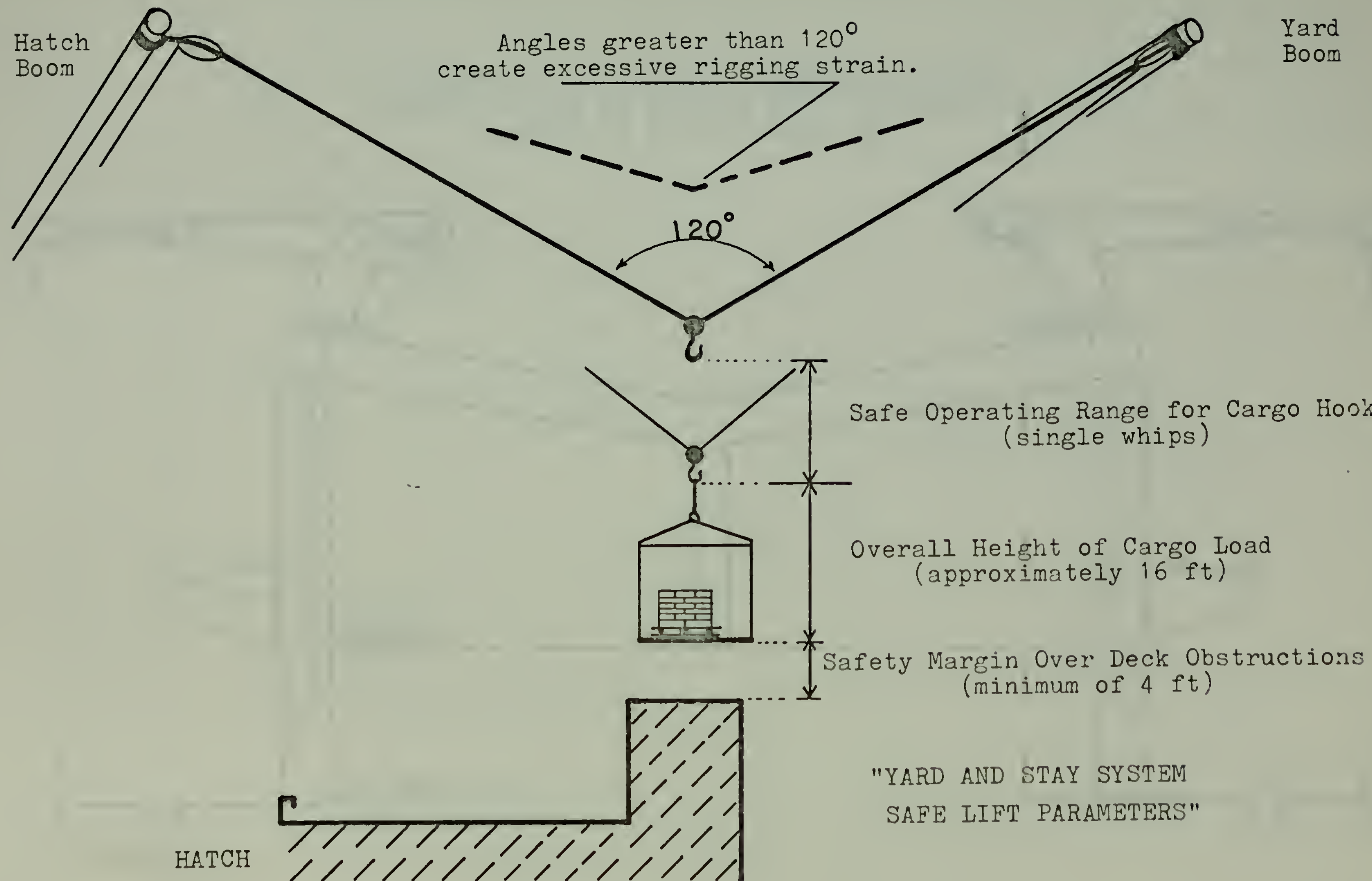
FIGURE 4

"ILLUSTRATION OF A CONVENTIONAL YARD AND STAY SYSTEM MOUNTED ON THE AOE."



NOTE: The location of guy lines and pendants which would interfere with fore and aft fork lift traffic and R.A.S. operations on the 01 deck. R.A.S. operations would take place in the immediate vicinity of the "M" frame on the 01 deck.

FIGURE 5



"YARD AND STAY SYSTEM
SAFE LIFT PARAMETERS"

FIGURE 6

"ILLUSTRATION OF HYDRAULIC TELESCOPING BOOMS
MOUNTED ON TOP OF HEAVY R.A.S. "M" FRAME
LOCATED ON AOE AT FRAME 196"

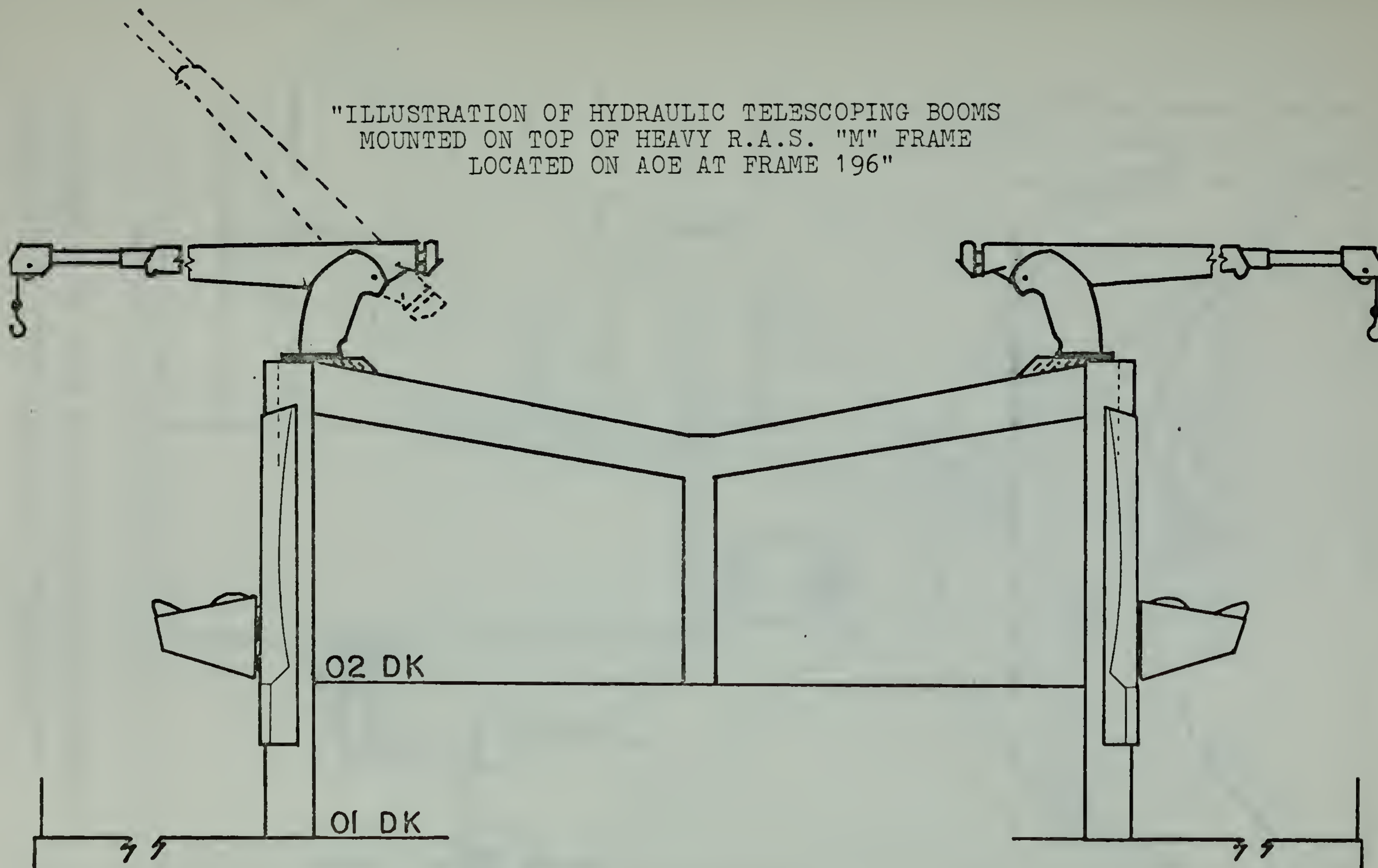
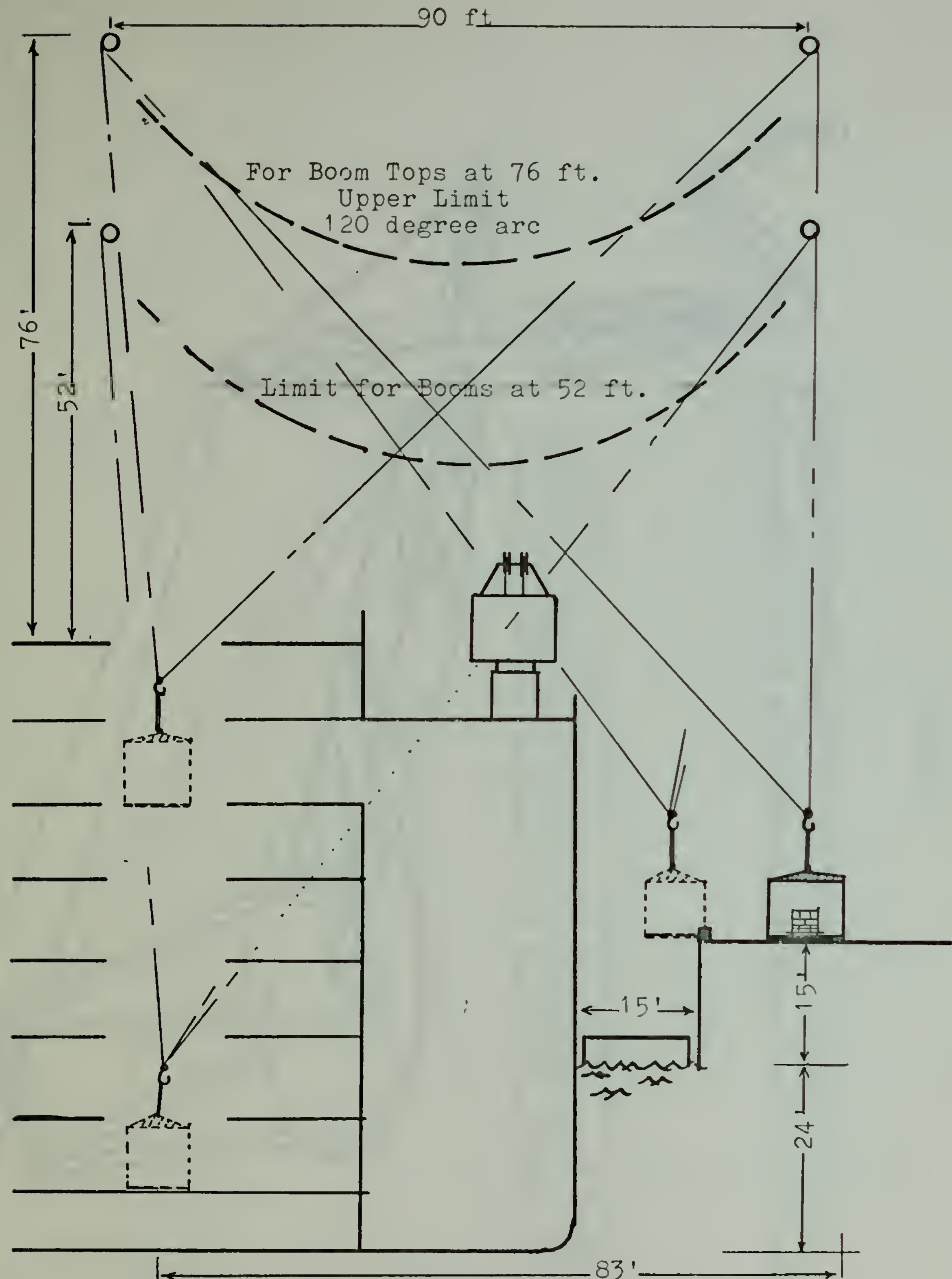
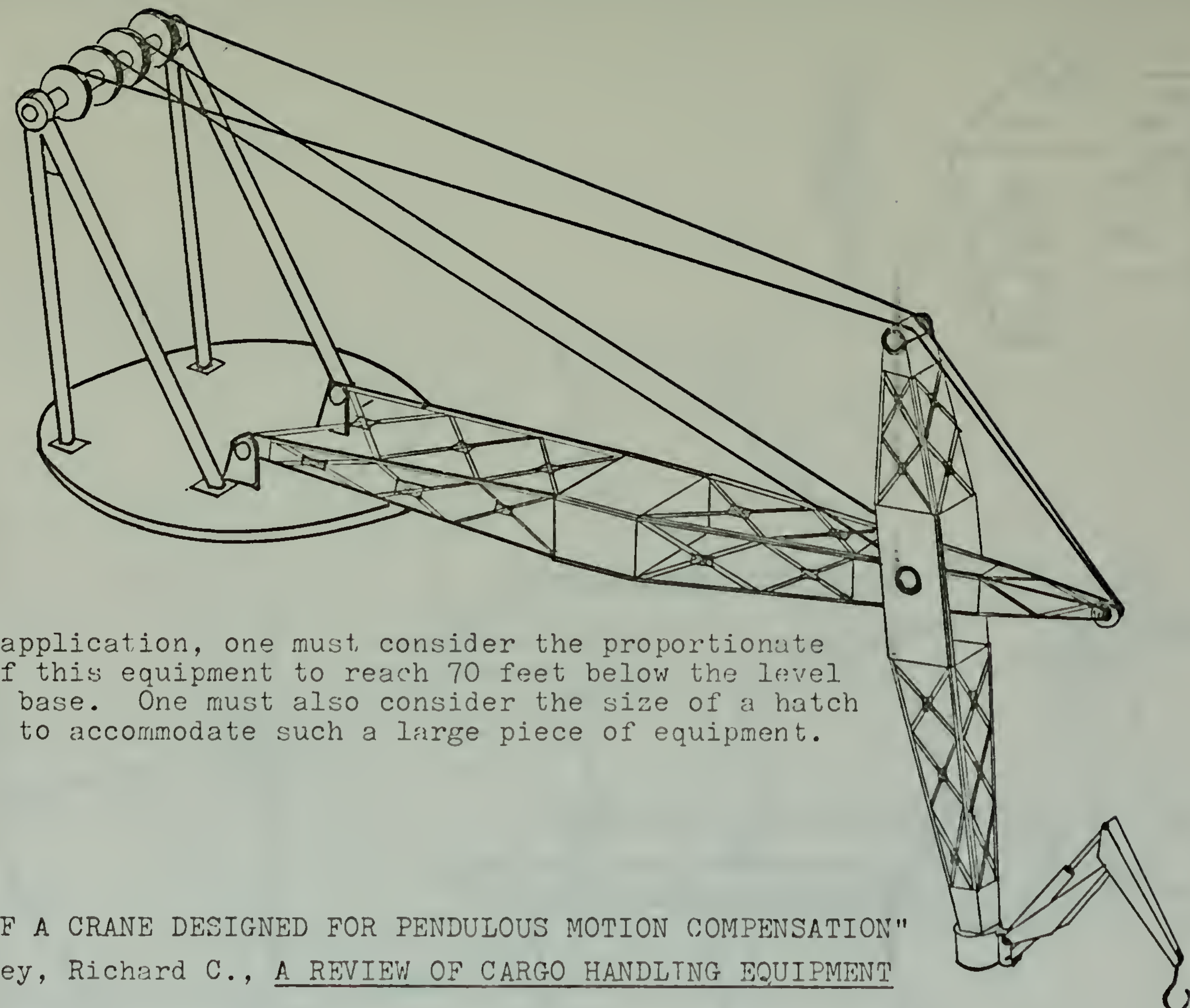


FIGURE 7



"ILLUSTRATION OF YARD AND STAY HOIST LINE ANGLES AND LIMITS IN HYPOTHETICAL AOE APPLICATIONS"

FIGURE 8

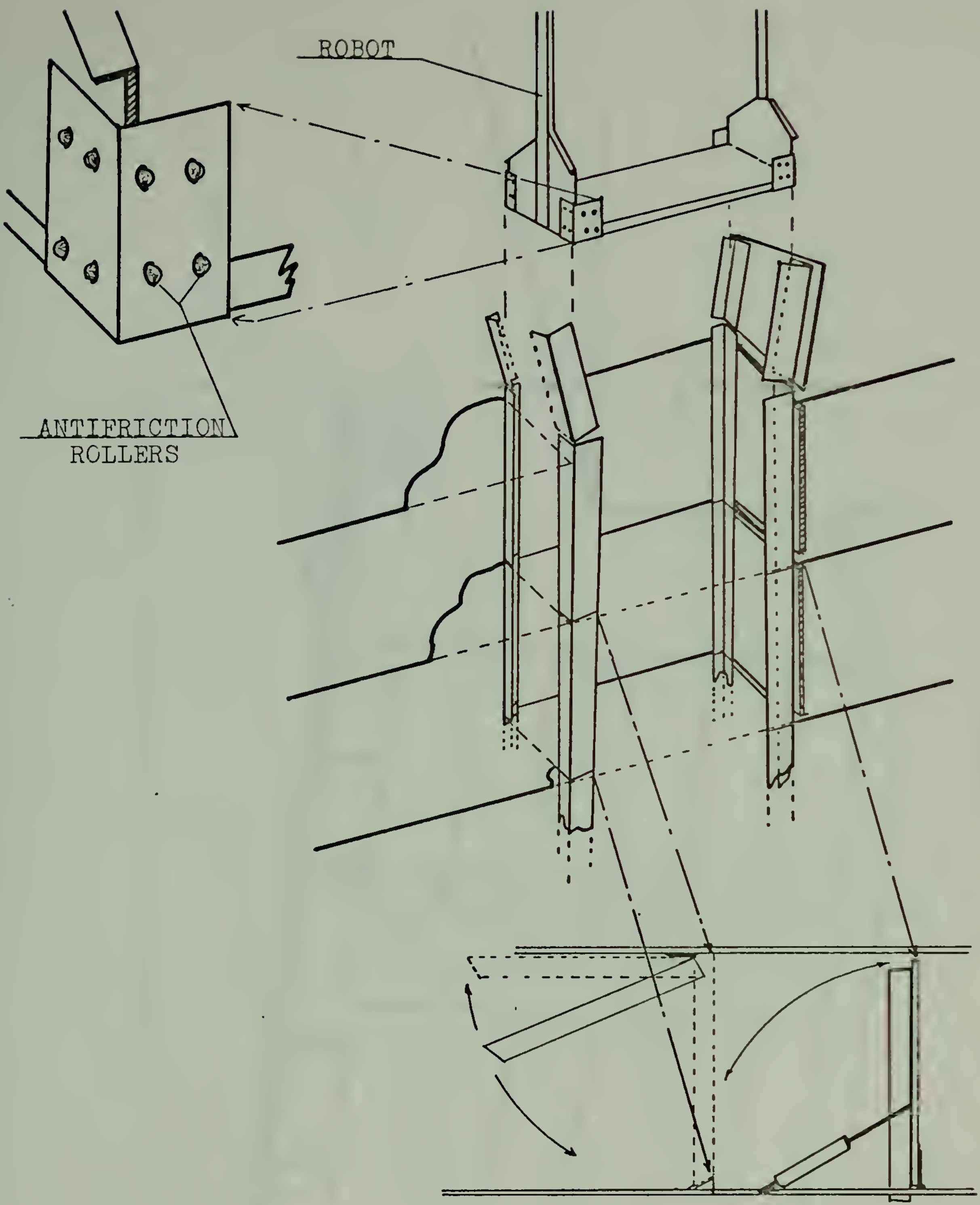


NOTE: For AOE application, one must consider the proportionate size required of this equipment to reach 70 feet below the level of the mounting base. One must also consider the size of a hatch system required to accommodate such a large piece of equipment.

"ILLUSTRATION OF A CRANE DESIGNED FOR PENDULOUS MOTION COMPENSATION"

SOURCE: Winfrey, Richard C., A REVIEW OF CARGO HANDLING EQUIPMENT

FIGURE 9



"ILLUSTRATION OF ROBOT GUIDES DESIGNED INTO AMIDSHIP HATCH SYSTEM TO ELIMINATE PENDULOUS MOVEMENT WITH CRANE-LOADING OPERATIONS.

FIGURE 10

"ILLUSTRATION OF A SIDE-LOADING TRANSPORTER"

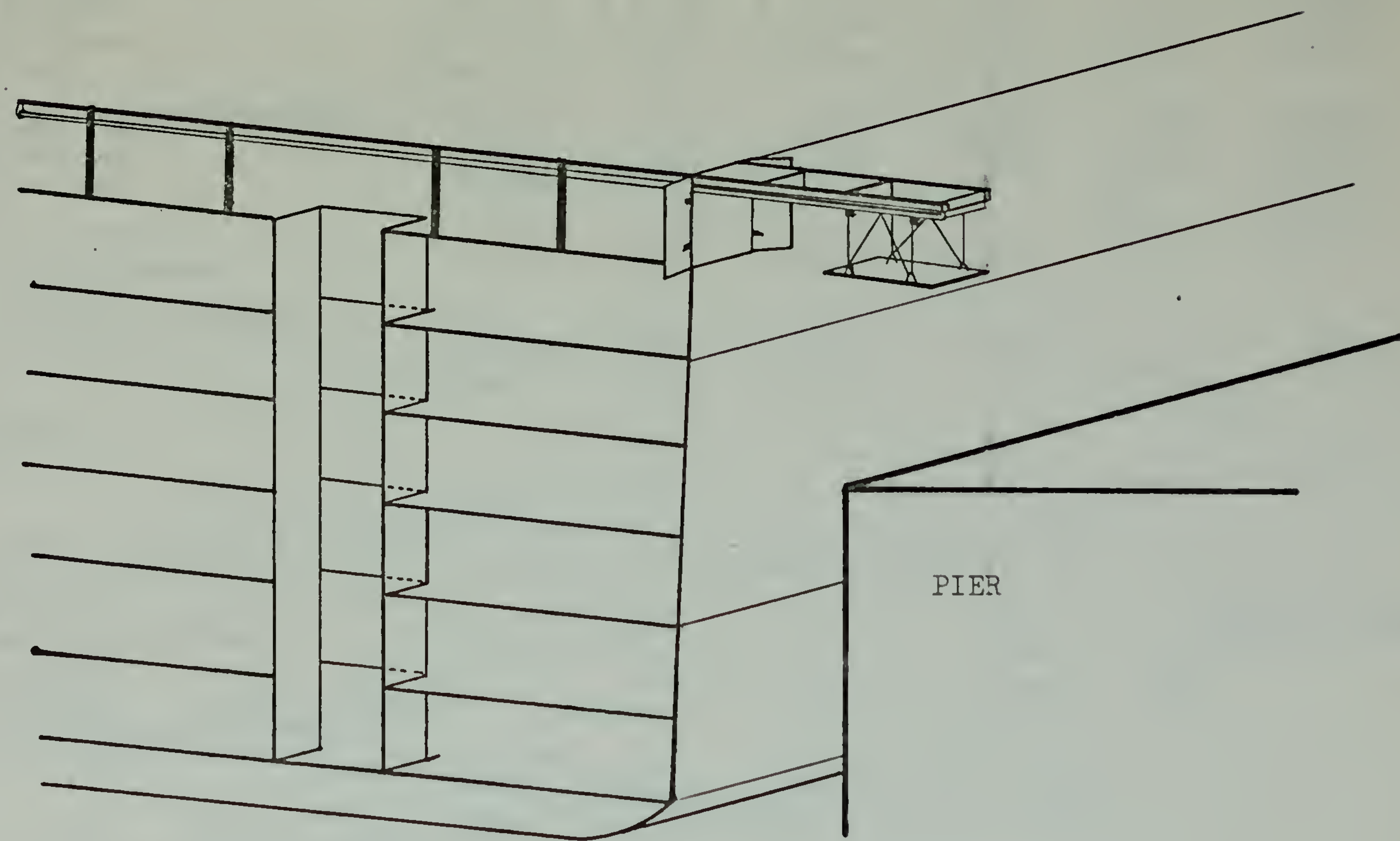


FIGURE 11

"SUMMARY COMPARISON OF ALTERNATIVES"

	A	B	C	D	E	F
COST OF ONE LOADOUT	$34,345	$ 7,257	$ 7,257	$ 8,327	$ 7,976	$ 8,993
Savings per loadout	Base Case	27,088	27,088	26,018	26,369	25,352
Annual savings	Base Case	81,266	81,266	78,056	79,108	76,056
AVERAGE COST per MEASUREMENT TON	$34.345	7.257	7.257	8.327	7.976	8.993
Palletized average	N.A.	3.51	3.51	6.58	6.08	7.53
Hand stow average	34.345	16.00	16.00	12.40	12.40	12.40
ELAPSED TIME IN SHIFTS	7.29	2.14	2.14	6.7	6.4	7.27
Aver. M.T./hour system	17.2	58.4	58.4	18.7	19.5	17.2
STEVEDORES REQUIRED per SHIFT						
Hand stow	43	31	31	12	12	12
Palletized	N.A.	24	24	10	10	10
EQUIPMENT HIRED						
Fork lifts	3	4	4	1	1	1
Cranes	1	2	2	0	0	0
EQUIPMENT (NAVY)						
Fork lifts	3*	5 (3)*	8 (3)*	1	1	1
Cranes on ship	1*	0	0		2 (one for ea. side of ship)	
Cargo booms and winches				2		
Pallet conveyors		1	2	1**	1**	
Pallet elevator		1		1**	1**	
Hatch system (through 7 decks)				1	1	
Package conveyors	2*					

Notes: * Already on board the ship.
** Yard and stay and crane systems not operable underway for issues.

FIGURE 12

"LOGIC STEPS FOR COMPUTING SYSTEM CAPACITY AND COSTS"
(Detailed steps explained in TABLE I)

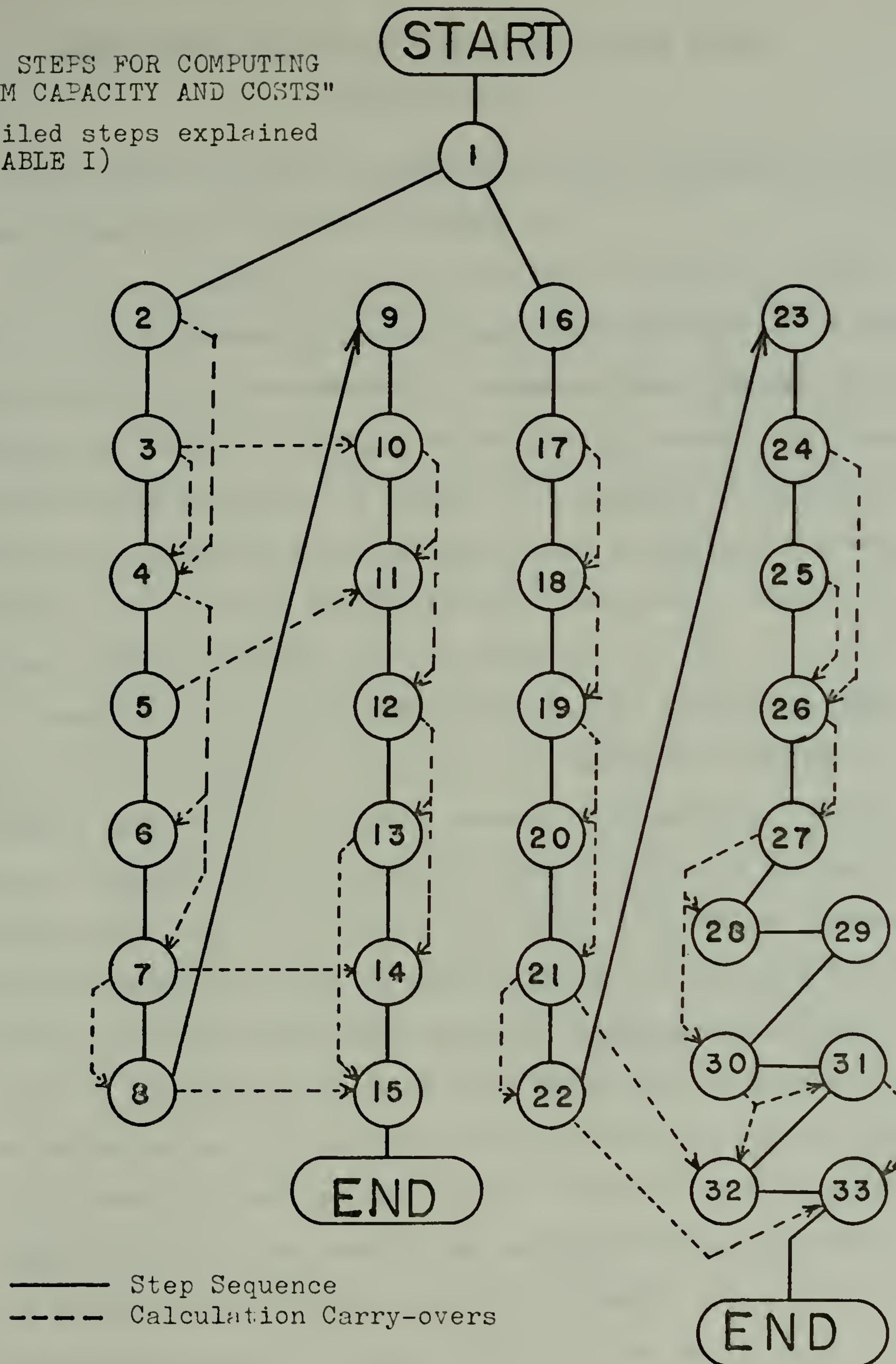


FIGURE 13

LOGIC FOR COMPUTING SYSTEM CAPACITY AND COSTS

(ASSUMPTIONS)

The following basic assumptions are incorporated in the logic procedures itemized in Table I.

Only one stevedore gang is assigned in a hold to work with one conveyance system and the gangs are hired in integer quantities. For instance, if a gang can stow 100 ton in a shift, and there is 150 ton of cargo to be stowed, one gang can stow the cargo in 1.5 shifts or two gangs can stow the cargo in .75 shifts if working with two conveyance systems. However, it is not a legitimate consideration to hire 1.5 gangs to stow the cargo in one shift.

Similarly, it is not practical to hire fractional fork lift or crane capacity, and these equipments are hired in integer quantities on a shift basis. Furthermore, if the system capability is 40 M.T./Hr, and a fork lift or crane capacity is, say, 35 M.T./Hr, two fork lifts or two cranes must be hired so as not to over constrain the system capability. Even if the second piece of equipment provides a total of 70 M.T./Hr, or 30 M.T./Hr more than is required on an hourly basis, the second piece of equipment must be hired (if it does not exceed some other constraint such as space congestion, etc.) to permit the overall system to achieve its 40 M.T./Hr potential. As with stevedore gangs, it is not legitimate to hire 1.14 fork lifts for one shift to accomplish this job.

TABLE I

LOGIC FOR COMPUTING SYSTEM CAPACITY AND COSTS

Step	Procedure
(1)	Select method for lowering cargo into the hold. Go to (2) if system has direct pier to hold lift capability as in alternatives D, E and F; go to (16) for systems requiring handling of cargo on 01 deck (alternatives A, B and C).
(2)	Compute M.T./Hr capacity of one fork lift and gang for stowage of palletized cargo in the hold.
(3)	Compute M.T./Hr capacity of equipment lifting cargo into the hold.
(4)	Constrain stowage to the lesser of (2) and (3). Result is system stow capacity for palletized cargo.
(5)	Compute M.T./Hr capacity of one fork lift on the pier feeding cargo to the system.
(6)	Compare the capacity of one fork lift on the pier to system stow capacity (4). Add one fork lift at a time until combined fork lift capacity on the pier just exceeds system stow capacity. Total number of fork lifts will be fork lift requirement for supporting system on the pier.
(7)	Divide standard 700 M.T. load by the system stow capacity in (4) and divide the result by 8 (hours in a shift) to obtain the number of shifts required to stow the palletized portion of the cargo load.
(8)	Identify manning requirements for stevedores, and equipment requirements in steps (4) through (6) above and the associated cost factors per hour. Multiply the cost factors by the number of shifts (7) required to find the cost of stowing the palletized portion of the cargo load.
(9)	Compute M.T./Hr capacity for one hand stow gang with a fork lift.
(10)	Compare (9) with (3) and constrain stowage capacity for hand stow cargo to the lesser capacity. This is the system capacity for stowing hand stow cargo.

TABLE I

(11) Compare (5) with (10) and add one fork lift if required to just exceed system hand stow capacity. Total number of fork lifts will be fork lift requirement on the pier to support the system hand stowage of cargo.

(12) Divide 300 M.T. by (10) and divide the result by 8 to obtain the number of shifts required to stow the hand stow portion of the cargo load.

(13) Identify the manning requirements for stevedores, and the equipment requirements in steps (9) through (11) above, and associated cost factors per hour. Multiply the cost factors by the number of shifts (12) to obtain the cost of stowing the hand stow portion of the cargo load.

(14) Add (12) and (7) to determine the total shifts required for the loading.

(15) Add (8) and (13) to determine the total cost for the load. This concludes the method for computing the capacity and cost of loading under alternative systems D, E and F.

(16) Assign one pallet stow gang and one fork lift to each strike down conveyance equipment.

(17) Compute the stow capacity of each gang in M.T./Hr.

(18) Compute the M.T./Hr strike down capacity of each conveyance system moving cargo from the 01 deck to the hold while supported by one fork lift on the 01 deck. Divide the strike down capacity of the conveyance equipment into the respective stow capability of the stevedore gang working that particular conveyance equipment as computed in (17). If the result is greater than one, add a fork lift to the 01 deck to feed the conveyance equipment until the strike down capacity is just equal to the respective gang stowage capacity, or to a maximum of 3 fork lifts on one conveyance. (However, the maximum fork lifts operable on the 01 deck for all the conveyance systems at one time is four. Additional fork lifts beyond this number causes excessive congestion between frames 174 and 196 on the 01 deck.) The lesser of gang stow capacity and strike down capability on each conveyance is the constrained stowage capacity. The sum of these constrained stowage capacities is the system pallet strike down capability.

TABLE I

(19) Compute M.T./Hr capacity for one crane lifting cargo from the pier to the 01 deck, and divide this figure into the system palletized strike down capability (18). If the result is greater than one, add one mobile crane, compute the total crane lifting capability and compare it with the palletized strike down capability (18). The lesser of these two capacities is the system constrained palletized stowage capacity.

(20) Compute M.T./Hr capacity of one fork lift on the pier. Divide this capacity into the system palletized stowage capacity (19). If the result is not an integer, round up to the next integer. This number is the quantity of fork lifts required on the pier to support the palletized loading operation.

(21) Divide 700 M.T. by the system palletized stowage capacity (20) and divide the result by 8. The result is the number of shifts required for stowage of the palletized portion of the load.

(22) Identify the manning requirements for stevedores and the equipment requirements in steps (16) through (20) above, and the associated cost factors per hour. Multiply the cost factors by the number of shifts (21) required to find the cost of stowing the palletized portion of the load.

(23) Assign one hand stow gang to each strike down conveyance equipment. Assign a gang with a fork lift in the storeroom where the conveyance has the capability to lower palletized quantities. (Except that with alternative A no fork lifts can be placed in the hold.)

(24) Compute M.T./Hr stow capacity of each gang.

(25) Compute M.T./Hr strike down capacity for each conveyance system lowering cargo to the hold from the 01 deck.

(26) Compare the stow capacity for each gang (24) to the strike down capacity for the respective supporting conveyance system (25). Constrain the stow capacity of each combination to the lesser of gang or equipment capability. The sum of these capacities is the system strike down capability for hand stow cargo.

(27) Compute the M.T./Hr lifting capacity for a crane lifting cargo from the pier to the 01 deck, and divide the crane capacity into the system strike down capability

TABLE I

(27) Continued.

for hand stow cargo (26). If the result is greater than one, add one mobile crane. Recompute the new crane lift capability and compare with the system strike down capability (26). The lesser capacity is the constrained system hand stowage capacity.

(28) Compute the M.T./Hr capacity of one fork lift on the 01 deck to feed the strike down conveyance systems. Divide the fork lift capacity into the system hand stow capacity (27). If the result is not an integer, round up to the next integer. This number is the number of fork lifts required on the 01 deck to support loading of the hand stow cargo. The total number of fork lifts on the 01 deck cannot exceed four. With alternative A, a minimum of one fork lift is assigned to each strike down conveyance because of the number of pallets and duplicate handlings of cargo required on the 01 deck.

(29) Compute the M.T./Hr capacity of one fork lift on the pier feeding the mobile crane(s). Divide this capacity into the constrained system stow capability (27). If the result is not an integer, round up to the next integer. This is the fork lift requirement on the pier to support the hand stow loading operation.

(30) Divide 300 M.T. by the constrained system hand stow capability (27), and divide the result by 8. This provides the number of shifts required to load the hand stow portion of the cargo load.

(31) Identify the manning requirements for stevedores and the equipment requirements in steps (23) through (29) above, and the associated cost factors per hour. Multiply the cost factors by the number of shifts (30) required to find the cost of stowing the hand stow portion of the cargo load.

(32) Add (21) and (30) to determine the total shifts required by the system to load the 1000 M.T. of cargo.

(33) Add (22) and (31) to determine the total cost of loading the 1000 M.T. load of cargo.

END OF ROUTINE.

TABLE I

AOEs 1 and 2 PROVISIONS LOADING HISTORY (1) (2)

SHIP AND YEAR LOADED		M.T. LOADED	GANG HOURS	M.T. per GANG HOUR	TOTAL COST	COST per M.T.	STANDARD ELAPSED TIME (3)
AOE 1	1966	1352	192	7.04	$45,000.	$33.28	8 days
AOE 1	1970	825	120	6.9	(4)	(4)	5 days
AOE 1	1971	1066	160	6.7	(4)	(4)	7 days
AOE 2	1972	1056	160	6.6	(4)	(4)	7 days
AOE 1	1973	967	144	6.7	$41,592.	$43.00	6 days
AOE 1	1974	480	96	5.0	$21,541.	$44.87	4 days
AOE 3 (5)	1973	1364	138	9.9	$46,585.	$34.15	6 days
Averages for AOEs 1 and 2		958	145	6.6			6.2 days

NOTES:

(1) Records of AOEs 1 and 2 loadings are held by the Fleet and Customer Service Officer NSC Puget Sound.

(2) Records of stevedore gang hours held by Mr. M. Knutson, Super Cargo, Pacific Northwest Outport, MTMTS, Pier 91, Seattle, Washington.

(3) A single 8-hour shift with three gangs equals 24 gang hours per day.

(4) Total cost figures are not readily available for these loadings.

(5) Entered for information only. Source: Records of Water Freight Division, NSC, Norfolk, Virginia.

FIGURE 14

SYSTEM COMPARISON: Manpower and Production

Hypothetical Assignments for Issues and Consolidations.

POSITIONS	PRESENT PACKAGE CONV. SYSTEM	PROPOSED PALLET ELEV/CONV SYS.
A. HAND STOW CARGO:		
Supervisor	1	1
Clerks (Doc. Control)	2	2
Fork Lift Drivers, 01 Deck	2	2
Fork Lift Drivers, in Hold	0	2
Work Party, 01 Deck	4	0
Work Party in Hold	10	10
TOTAL ASSIGNED	19	17
ISSUE CAPACITY, M.T./HR	10	17
B. PALLETIZED CARGO:		
Supervisor		1
Clerks		2
Fork Lift Drivers, 01 Deck		2
Fork Lift Drivers, in Hold		2
TOTAL ASSIGNED	N/A	7
ISSUE CAPACITY, M.T./HR		38 to 42

EXAMPLE:

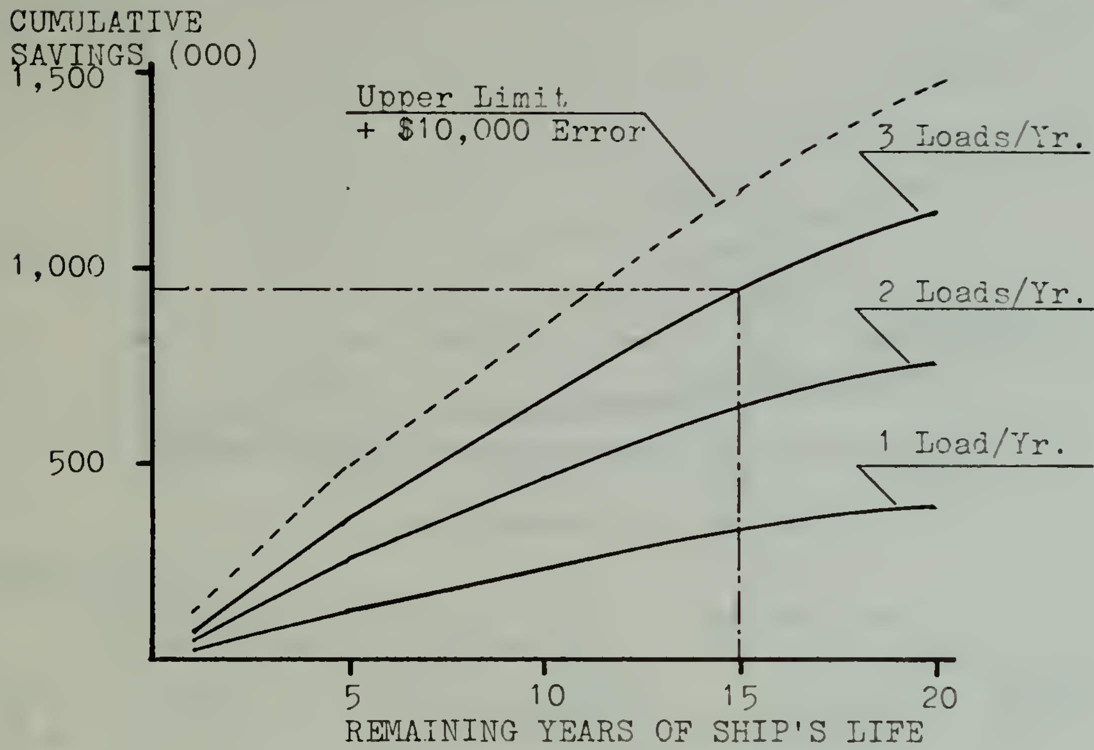
Issues for one day of 150 measurement ton to three ships (one CVA and two Destroyers, four hours alongside):

Present System:
150 ton hand stow @ 10 M.T./Hr =15 Hours
(Start 11 hours prior rendezvous)

Pallet Conv/Elev System:
Full pallet loads: CVA=8, DDs=2, for 10MT= .25 Hours
140 ton hand stow @ 17 M.T./Hr = 8.3 "
(Start 4.5 hours prior rendezvous)

FIGURE 15

"SENSITIVITY OF SAVINGS TO TIME AND NUMBER OF LOADOUTS"



ANNUAL SAVINGS SENSITIVITY TO ERROR OVER TIME
(+ & - $10,000 error per loading discounted at 10%)

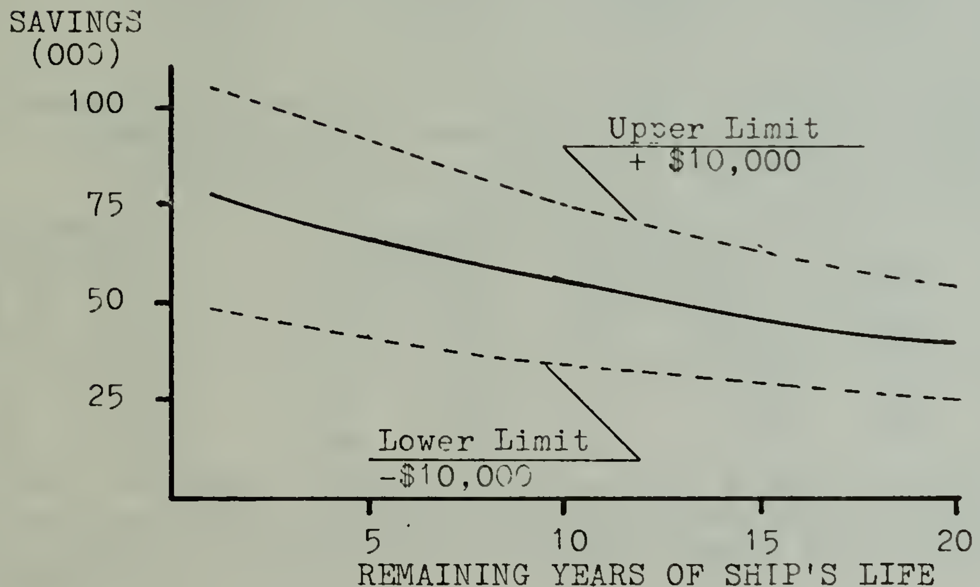
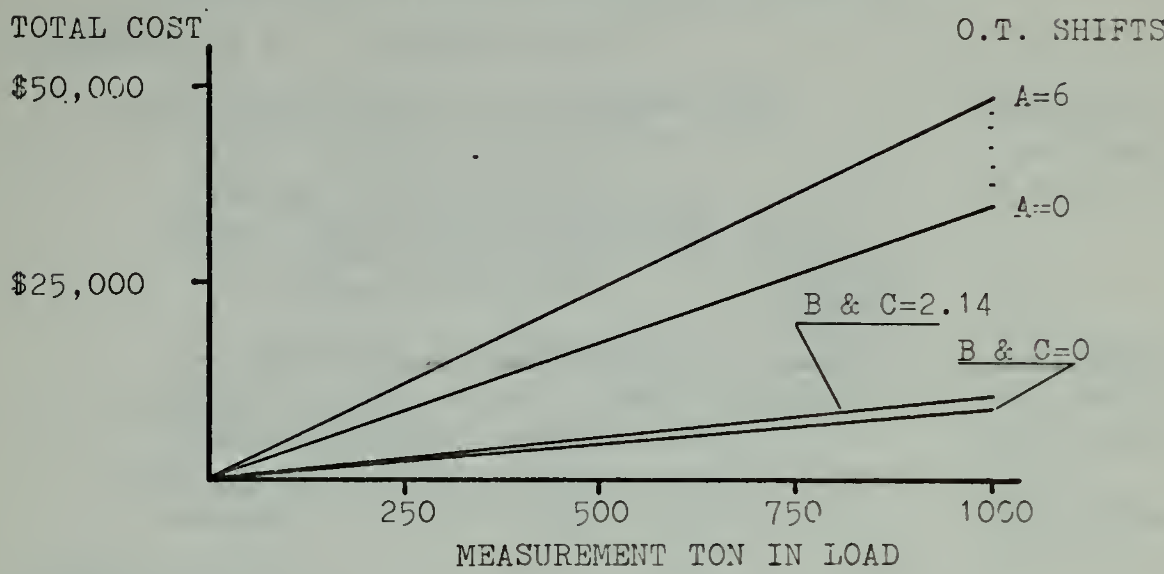


FIGURE 16

"COMPARISON OF OVERTIME EFFECTS ON TOTAL COST"
(Alternative A vs Alternatives B and C)



ALTERNATIVE A:

Maximum of 6 overtime shifts (long week end).
Elapsed Time is 7.29 shifts.

OVERTIME SHIFTS @ $6,544 Nr.	Cost	STANDARD SHIFTS @ $4,363 Nr.	Cost	EQUIP. COST $2,537	TOTAL COST
1	$ 6,544	6.29	$27,443	$2,537	$36,524
2	13,088	5.29	23,080	2,537	38,705
3	19,632	4.29	18,717	2,537	40,886
4	26,176	3.29	14,354	2,537	43,067
5	32,720	2.29	9,991	2,537	45,248
6	39,264	1.29	5,628	2,537	47,429

ALTERNATIVES B and C:

Maximum of 2.14 overtime shifts, equals elapsed time.
Assume overtime is applied to palletized stow first.

PALLETIZED O.T. SHIFTS @ $2,974 Nr.	Cost	HAND STOW O.T. SHIFTS @ $4,749 Nr.	Cost	STD SHIFTS @ $3,166 Nr.	Cost	EQUIP. COST $905	TOTAL COST
.76	$2,974	.24	$1,140	1.14	$3,609	$905	$ 8,628
.76	2,974	1.24	5,889	.14	443	905	10,211
.76	2,974	1.38	6,554	0.0	0	905	10,433

NOTE: Equipment cost for alternatives B and C is the cost of equipment for .76 shifts of palletized stow, $474, plus the cost of equipment for hand stow cargo, $312 times 1.38 shifts.

FIGURE 17

OVERTIME COST COMPUTATIONS FOR FIGURE 17

ALTERNATIVE A. (All hand stow.)

Total Loading Cost at Standard Time		$34,345.00
Divide by Number of Shifts		÷ 7.29
Average Cost Per Shift		$ 4,711.00
Less: Equipment Charges Per Shift:		
3 Fork Lifts @ $4.50/Hr	$13.50	
1 Crane @ $30./Hr	30.00	
	$43.50	
Multiply by Hours/Shift	X 8.0 =	- 348.00
Average Stevedore Cost at STD. Time/Shift		$ 4,363.00
Multiply by Overtime Factor		X 1.5
Overtime Average Shift Cost for Stevedore Personnel		$ 6,544.00

ALTERNATIVE B AND C

HAND STOW:		
Total Cost $16. X 300 M.T.		$ 4,800.00
Divide by Number of Shifts		÷ 1.38
Average Cost Per Shift Hand Stow		$ 3,478.00
Less Equipment Charges Per Shift:		
2 Fork Lifts @ $4.50 Hr	$ 9.00	
1 Crane @ $30./Hr	30.00	
	$39.00	
Multiply by Hours/Shift	X 8.0 =	- 312.00
Average Stevedore Cost at STD. Time/Shift		$ 3,166.00
Multiply by Overtime Factor		X 1.5
Overtime Average Shift Cost for Hand Stow		$ 4,749.00
PALLET STOW:		
Total Cost $3.51 X 700 M.T.		$ 2,457.00
(Less than 1 shift @ 918.4 M.T./Shift)		
Less: Equipment Charges per Shift:		
4 Fork Lifts @ $4.50/Hr	$18.00	
2 Cranes @ $30./Hr	60.00	
	$78.00	
Multiply by Hours/Shift	X 8.0	
	$624.00	
Multiply by Shift Ratio (700 ÷ 918)	X .76 =	- 474.00
		$ 1,983.00
Multiply by Overtime Factor		X 1.5
Overtime Average Shift Cost for Pallet Stow		$ 2,974.50

TABLE II

"COMPARISON OF SYSTEM COST SENSITIVITY TO PERCENTAGE OF LOAD PALLETIZATION"
(1,000 Measurement Ton Load)

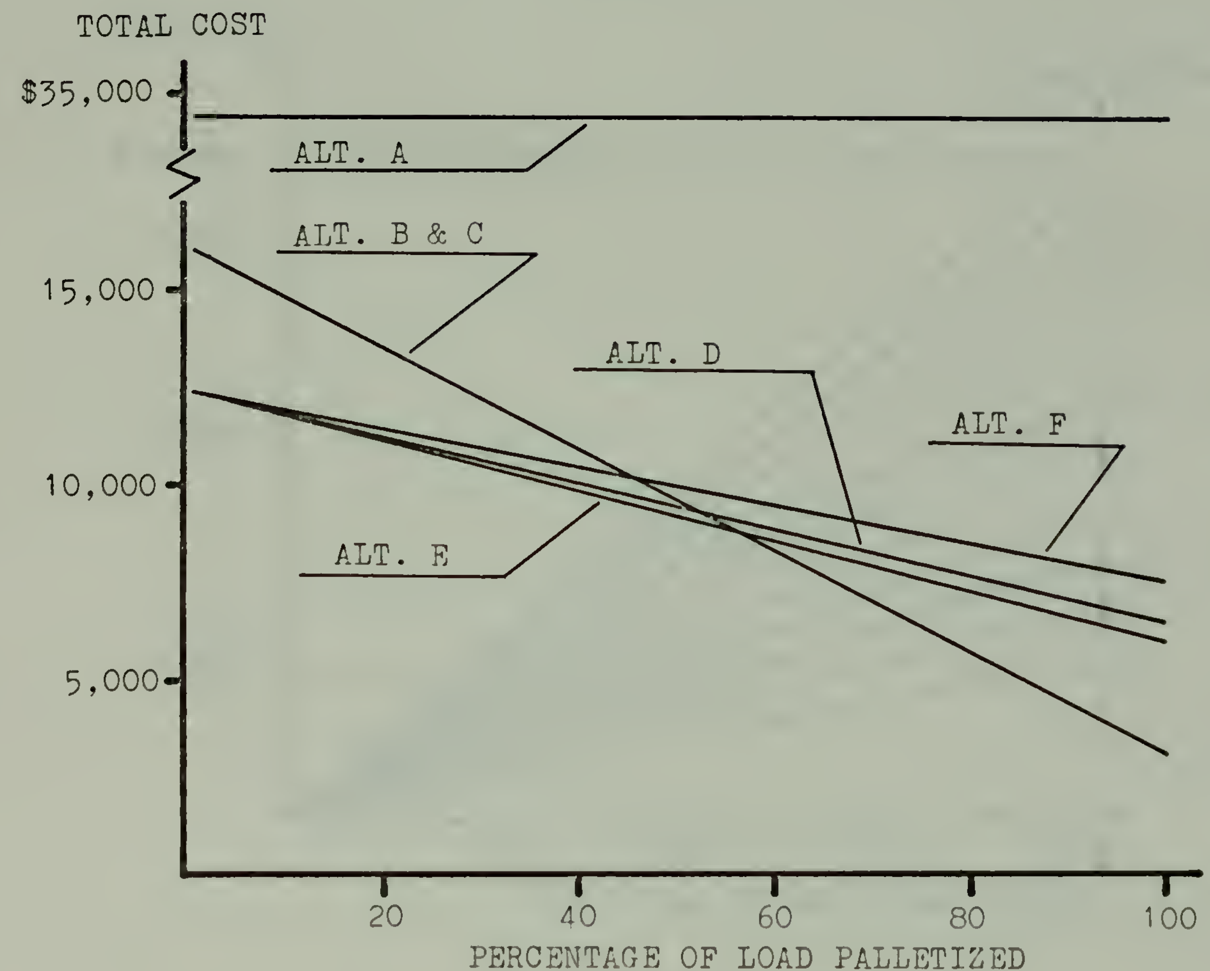


FIGURE 18

"SYSTEMS B AND C SENSITIVITY OF TOTAL LOADING COST TO PERCENTAGE OF PALLETIZATION"

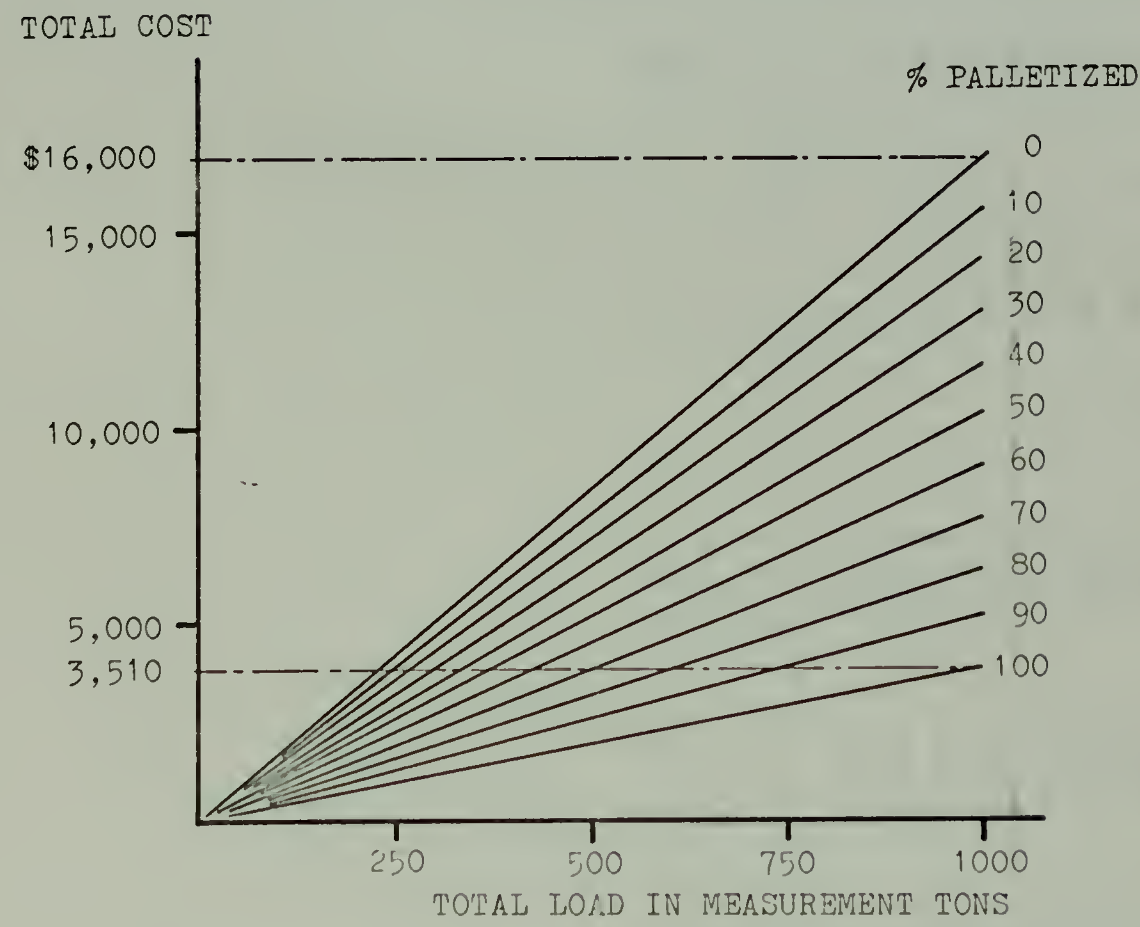


FIGURE 19

"SENSITIVITY OF COST TO THE PERCENTAGE OF PALLETIZATION"

PERCENTAGE OF LOAD Palletized/Hand Stowed			ALTERNATIVES B & C	D	E
0	/	100	$16,000	$12,400	$12,400
10	/	90	14,751	11,818	11,768
20	/	80	13,502	11,236	11,136
30	/	70	12,253	10,654	10,504
40	/	60	11,004	10,072	9,872
50	/	50	9,755	9,490	9,240
60	/	40	8,506	8,908	8,608
70	/	30	7,257	8,327	7,976
80	/	20	6,008	7,744	7,344
90	/	10	4,759	7,162	6,712
100	/	0	3,510	6,580	6,080

TABLE III

"SENSITIVITY OF SYSTEM ELAPSED TIME":
(As a Function of Load Size and Percentage Palletization)

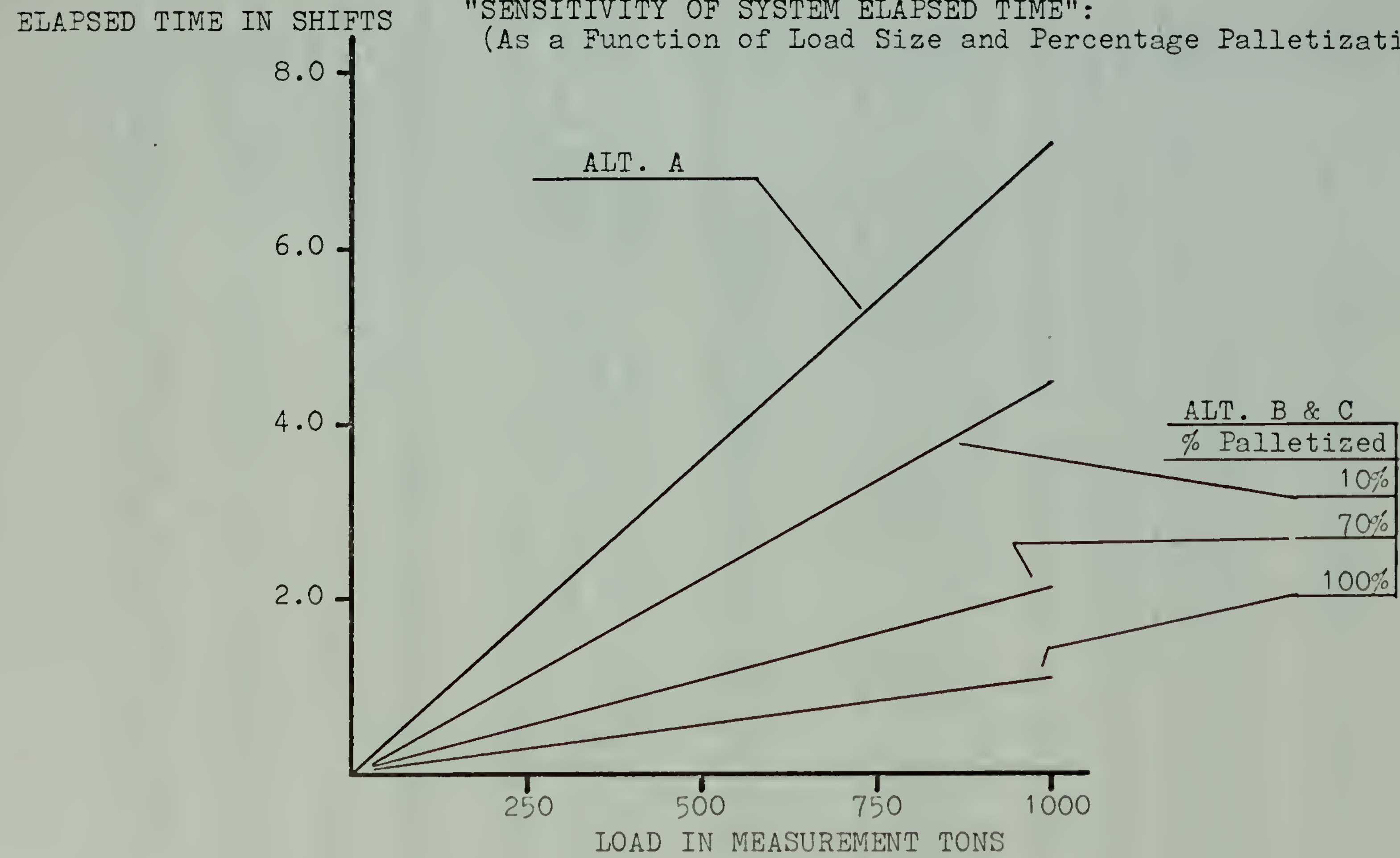


FIGURE 20

BIBLIOGRAPHY

Apple, James M., Material Handling Systems Design, Ronald Press Co., New York, 1972.

Arnott, David, Design and Construction of Steel Merchant Ships, The Society of Naval Architects and Marine Engineers, New York, 1955.

Besecker, John A., An Analysis of Connected Replenishment Operational Data: the distribution of CONREP service time, M.S. Thesis, Naval Postgraduate School, Sept. 1970

Bureau of Naval Personnel, Principles of Stability in Shiploading, NAVPERS 91076, March 1949.

Bureau of Naval Personnel, Seamanship, NAVPERS 16118-A, 1951.

Commander Naval Ships System Command Letter PMS 390:MT:alc, 9200, Ser 255-PMS-390, to Distribution List, Subject: Handling and Storage of Unitized Cargo in AOE Class, Enclosure (1) Report "Operational Evaluation of USS Detroit (AOE-4) Provisions Handling System During Mediterranean Deployment LOGREP 2-71."

Commander Service Force Atlantic Instruction 4423.3H, Subject: Atlantic Fleet Mobile Logistics Support Force Provisions/BIG-40 Load List: promulgation of, 13 April 1971.

Commanding Officer, USS Camden (AOE-2) Letter, AOE2:JAP:dp, 4400, Ser 12, to Commander Service Group Three, Subject: Mobile Supply Support Cruise Report, 6 January 1974.

Department of the Air Force, Economic Analysis Handbook, 18 October 1972.

Department of the Navy, Storage and Materials Handling, NAVSUP PUB 284, 31 July 1963, Change 26, 31 May 1972.

Federal Reserve Bank of St. Louis, National Economic Trends, March 1974.

Ford, Alfred G. and Webster, J.K., Handling and Stowage of Cargo, International Text Book Col, Scranton, Pa. 1952.

Grève, Ing E., "Rationalizing Cargo Gear for Handling General Cargo on Ships," Ships Gear 1966, Fishing News (Books) Limited, London 1966.

Hepburn, D. and Gibson, J. B., "Developments in Side Loading Transporters and Deck Auxiliaries," Ships Gear 1966, Fishing News (Books) Limited, London, 1966.

Horton, H. L., Machinery's Handbook, Industrial Press Inc., New York, 1971.

Lawrence, D. A., "Developments in Cargo Handling Techniques," Ships Gear 1966, Fishing News (Books) Limited, London 1966.

McMillen, L. K. jr., Application of Cost Effectiveness Techniques to Selection of Preferred Warship Characteristics, M.S. Thesis, Naval Postgraduate School, 1966.

Nagel, R., Scholes, R., and Hover, P., "Progress in Hatch Cover Actuation", Ships Gear 1966, Fishing News (Books) Limited, London, 1966.

Naval Ship Engineering Center, Addendum to Cost and Feasibility Study of Recommended Improvements to AOE Class Provisions Handling and Stowage System, 7 March 1972.

U. S. Naval Supply Research and Development Facility Study, Off-Loading Military Supplies from Cargo Ships in Unimproved Port Areas, by Planning Research Corporation, Washington D. C., 1 August 1966.

USS Detroit message 101125Z May 1973.

Staniar, William, Plant Engineering Handbook, McGraw Hill Book Company, New York 1959.

Winfrey, Richard C., A Review of Cargo Handling Equipment, Naval Postgraduate School, 1 October 1971.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
3.	Department Chairman, Code 55So Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	2
4.	Asst Professor J. P. Hynes Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
5.	LCDR David Karl Anderson, USN Staff CINCPAC - Box 20 FPO San Francisco 96610	1
6.	Cdr. P. W. Benediktsson Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
7.	Commander Naval Ship Systems Command PMS 427 Washington, D. C. 20360	1
8.	Commander Naval Supply Systems Command Library, Building 3, Room 528 Crystal Mall Washington, D. C. 20360	1

Thesis
A4458
c.1

152170

Anderson
An analysis of alternative methods for loading provisions aboard AOEs 1 and 2.